CRM 96-20 / April 1996

Utility of Ecological Risk Assessments

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REPORT DOCUMENTATION PAGE

Form Approved
OPM No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
April 1996

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Utility of Ecological Risk Assessments

5. FUNDING NUMBERS
C - N00014-91-C-0002
PE - 65154N
PR - R0148

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Center for Naval Analyses
4401 Ford Avenue
Alexandria, Virginia 22302-0268

8. PERFORMING ORGANIZATION REPORT NUMBER
CRM 96-20

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Assistant Secretary of the Navy (Installations and Environment)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Cleared for Public Release

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Ecological Risk Assessments (ERAs) are performed at hazardous waste cleanup sites under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) program to determine the risk that contaminants pose to the environment. A number of concerns have been expressed with respect to ERAs and other studies conducted at CERCLA sites including the following: Too much effort is being spent on "studies" instead of remedies; and remedies are largely determined on the basis of human health risk. As a result of these concerns, the Assistant Secretary of the Navy (Installations and Environment) asked the Center for Naval Analyses to conduct a study of the utility of ecological risk assessments. This study was to review the ERA process in general and address specific issues. This report documents the results of the study.

14. SUBJECT TERMS
Chemicals, contamination, costs, ecology, environmental impact, environmental protection, hazardous wastes, pollution, risk, waste disposal, waste management

15. NUMBER OF PAGES
100

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
SAR

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Summary

Background

Ecological risk assessments (ERAs) are performed at hazardous waste cleanup sites under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) program to determine the risk that contaminants pose to the environment. A number of concerns have been expressed with respect to ecological risk assessments and other studies conducted at CERCLA sites including the following:

- Too much effort is being spent on "studies" instead of remedies
- Remedies are largely determined on the basis of human health risk and any applicable cleanup standards in place as opposed to ecological risk.

As a result of these concerns, the Assistant Secretary of the Navy (Installations and Environment) (ASN(I&E)), asked the Center for Naval Analyses (CNA) to conduct a study of the utility of ecological risk assessments. This study was to review the ERA process in general and address the following specific issues:

- Are ERAs revealing significant ecological problems?
- If so, are the results of these assessments actually being used to formulate cleanup strategies?
- What are the dollar costs of these assessments?
- Is there duplication of effort across the Navy in the determination of the effects of contaminants on specific organisms?
- Are there readily identifiable parameters related to a site which could be used to determine when an ecological risk assessment is appropriate?

This report documents the results of the study.

Approach

Our analysis approach included the following:

- Reviewing the requirements and guidelines for conducting ERAs in CERCLA
- Obtaining a sample of Navy ERA reports, supporting documentation and costs
- Determining what ecological risks were uncovered at the sites and, where possible, how ERA results influenced remediation decisions.

The review of regulatory guidance determined the legal requirement for ERAs. Guidance from EPA and other agencies described how ERAs should be conducted.

We contacted Naval Facilities Engineering Command Engineering Field Divisions and Activities (NAVFAC EFDs/EFAs) around the country and obtained ERA reports for a wide variety of Navy restoration sites. We obtained accompanying Record of Decision documents from the EFD/EFA and from an Environmental Protection Agency (EPA) database called RODS. Where possible, EFDs/EFAs also provided data on the costs of these ERAs.

We reviewed the content of these reports and attempted to answer the following questions:

- What is the science involved in conducting ERAs?
  - How are they conducted at DON CERCLA sites?
  - How do they characterize risk to ecological resources?
- How are the results of ERAs used in the remedial process?
  - What have risk managers and decision-makers done with these studies?

Our data set consisted of 80 ERAs from 17 Navy installations. All but one of the installations are listed on the National Priority List (NPL). The ERAs ranged in scale from the investigation of a single site to investigation of large areas contiguous to the contamination site. The scope of work ranged from screening-level to in-depth baseline assessments with the latter incorporating extensive laboratory (bioassay) work. All of the ERAs we reviewed were conducted as part of the Site Investigation (SI) or Remedial Investigation (RI) process. *None* involved an assessment of the ecological risk posed by potential remedy selections at a site (although the information collected in the RI would be relevant to the latter assessment).

Principal findings

Based on our analysis, we found:

- Every ERA revealed the presence of at least one contaminant in concentrations that exceeded screening levels indicative of the potential for ecological risk.
- Despite this fact, half of the ERAs indicated "minimal" risk to the environment. This finding was typically determined by evidence of a poor habitat for ecological resources.
- Of the other half, most indicated "some" risk, and a few indicated "likely" risk.
  - — In no case was the risk quantified in terms of likelihood or magnitude.
  - — ERAs in this category called for further study over half the time.
  - — Potential remediation criteria were rarely indicated.
- The precision of the risk estimate appeared to be unaffected by the scope of the assessment. Screening-level and in-depth assessments characterized risk in the same way.
- Twenty-seven of the 80 sites we examined had reached the ROD (or remedy selection) stage. Of these, we identified six ERAs which appeared to have had an impact on the remedy selection. It is important to note, however, that ERAs have only recently become an important part of the RI/FS process. Many

of the sites in our database will have RODs finalized in FY 1996 and FY 1997.

- The costs of ERAs varied widely ranging from less than $10 thousand to more than $1 million. The most expensive ERAs tend to be in-depth assessments involving large amounts of laboratory (bioassay) work and including a significant marine component.
- Duplication of effort across the Navy in determining the effects of contaminants on organisms does not appear to be a serious problem.
- Our observations of risk characterization at Department of Navy CERCLA sites and our review of the ecological risk literature lead us to conclude that decision-makers (site risk managers) should expect to receive only qualitative estimates of risk to ecological resources from an ERA.

Recommendations

Based on these findings, we provide the following observations and recommendations.

First, a realistic appreciation of the limits of ERAs in determining risks and supporting remediation decisions is required. ERAs as presently conducted for the DON provide quantitative estimates of risk to individual organisms, but only qualitative risk estimates to populations, communities, or ecosystems. Given the limitations in ERAs, the DON should not expect that expanded ERA scopes or additional study will lead to a more precisely quantified risk. Because risk estimates are qualitative, it may be easy to default to other criteria such as applicable or relevant and appropriate requirements (ARARs) or human health risk estimates. Perhaps general qualitative findings are sufficient information to allow remediation decision-makers to weigh ecological considerations in deciding if and how to remediate a site. If not, the question should be addressed about the current usefulness of this information in the remedial process.

Second, the DON (perhaps in conjunction with the other services) should develop guidance or policy for how to proceed in cases in which exceedances are found but other compelling evidence of ecological risk (such as visible evidence of a stressed or damaged ecosystem) is lacking. Screening exceedances have always been found. As a result, using a tiered or phased approach as is now advocated in guidance will almost always lead to more study. And as we discovered, the resulting risk estimate is still qualitative.

Third, observational criteria could be applied with regard to habitat suitability or visible effects before investing large amounts of effort in ERAs. We saw instances in which an ERA was performed, only to conclude with a statement that the habitat is unsuitable for various other reasons, so there is no point in cleaning it up. Two EFDs noted, however, that they have not had success with this argument in their EPA regions. We also note that most ERAs did not reveal evidence of stressed or damaged communities and ecosystems despite the presence of contaminant exceedances.

Finally, we emphasize that only DON ERAs were reviewed for this study. At this time, we do not know if our findings are similar to those that would be found in a review of ERAs conducted for other services and federal agencies. Examining these ERAs would be useful to place DON ERAs in the context of the larger program.

Introduction

Background

The National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300) prescribes procedures for conducting site assessments, contaminant characterization, and feasibility studies for remedial alternatives at contaminated sites. Human health risk assessments (HHRAs) and ecological risk assessments (ERAs) are components of this assessment process. The Department of Defense (DOD) has been criticized by Congress for expending too much effort on "studies." This perception has contributed to the reduction of the Defense Environmental Restoration Account (DERA)[1] budget requests in the last three fiscal years [1].

A number of potential concerns exist with respect to ecological risk assessments including the following (taken from the study tasking [1]):

- Although the leadership of DOD and EPA have agreed on the need to streamline the cleanup process, field-level regulators continue not only to require ecological risk assessments, but in some cases, have required the Navy to expand the scope of ongoing assessments.
- Remedies are largely determined on the basis of human health risk and any applicable cleanup standards in place. As a result, the Navy suspects that the value of detailed ecological risk assessments is marginal in most cases.

As a result of these concerns, the Assistant Secretary of the Navy, Installations and Environment (ASN(I&E)) asked CNA to conduct a study of the utility of ecological risk assessments. CNA was asked to

1. The DERA account has recently "devolved" to the individual services.

review the ERA process in general and address the following specific issues:

- Are these risk assessments revealing significant ecological problems?
- If so, are the results of the assessments actually being used in formulating cleanup strategies?
- What are the dollar costs of these assessments?
- Is there duplication of effort across the Navy in the determination of the effects of contaminants on specific organisms?
- Are there readily identifiable parameters related to a site which could be used to determine when an ecological risk assessment is appropriate?

This report documents the results of the study.

Approach

Our approach consisted of addressing the following three questions:

- What are the requirements and guidelines for conducting ERAs under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)?
- What is the science involved in ERAs?
  — In particular, how is risk estimated and characterized?
- How are the results of ERAs used in the remedial process?

In the first phase of the study, we reviewed regulatory guidance to determine the legal requirement for ERAs under CERCLA (or "Superfund" as it is more commonly known). We also reviewed U.S. Environmental Protection Agency (EPA) and other agency guidance on how ERAs should be conducted, and traced the evolution of the use of ERAs in CERCLA.

In the second phase, we reviewed the Department of the Navy (DON) Installation Restoration (IR) program plan [2] and identified DON sites where ERAs have been conducted. We then contacted Naval

Facilities Engineering Command (NAVFAC) Engineering Field Divisions/Activities (EFDs/EFAs) around the country and obtained a sample of ERA reports. In some cases, we obtained additional documents including the accompanying human health risk assessment and Record of Decision (ROD). We also obtained ROD information from an EPA database called RODS. Where possible, EFDs and EFAs also provided data on the costs of the ERAs.

We reviewed the content of these reports and assessed how the ERA characterized the environmental risk at each site and what impact they had on remediation decisions.

Organization of this report

The next section of the report provides background on the legal requirements for ERAs and briefly discusses their evolution in the Superfund program. The following section describes the ERA process in some detail as it has been applied at DON sites. It contrasts ERAs with HHRAs and focuses, in particular, on how risk is characterized in the ecological assessment. As we discuss later in the report, risk characterization is the key component of the ERA process. The characteristics of the data set we reviewed are covered in the following section. We then conclude with a discussion of our principal findings and recommendations.

ERA background and legal requirements

Definition and purpose of an ERA

The EPA defines an ecological risk assessment as "the process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" [3]. ERAs can be performed in response to a number of environmental statutes. For the purposes of this study, we are primarily interested in ERAs associated with the Superfund program. "Ecological risk assessment" as used in this program refers to "a qualitative and quantitative appraisal of the actual or potential impacts of a hazardous waste site on plants and animals other than humans and domesticated species" [4].

An ERA provides some of the information required to make a risk management decision. The risk manager uses information from risk assessments (along with other studies) and the list of remedial options to select a preferred cleanup option. In the Superfund program, the purpose of an ERA is to assess the risks of chemicals at hazardous waste sites to the environment. An assessment of the potential ecological risk of remedial options is also part of the process. Although risk assessment and risk management are separate processes, the risk assessment must provide information in a manner that is useful to the risk manager.

Legal requirements

The primary statute governing remediation of hazardous waste sites in this country is the Comprehensive Environmental Restoration, Compensation, and Liability Act (1980) as amended in the Superfund Amendments and Reauthorization Act (SARA,1986). Section 120 of SARA provides for federal facility compliance, both substantively and procedurally, to the same extent as any private entity [5].

This compliance includes requirements related to listing on the National Priority List (NPL). The primary guidance document for CERCLA response actions is the National Contingency Plan (NCP) [6]. The NCP sets forth the procedures which must be followed by EPA and private parties in selecting and conducting CERCLA response actions.

The requirement to include environmental concerns together with human health concerns in remediating hazardous waste sites can be found throughout CERCLA and the NCP. Numerous sections of CERCLA refer to protection of human health *and the environment* as parts of a whole. The following examples are illustrative:

- Section 104(b)(1) discusses studies and investigations to identify "... the extent of danger to public health or welfare or the environment" posed by releases of hazardous substances, pollutants, and contaminants.
- Section 105(a)(2) states that the NCP should include "... methods for... remedying any releases or threats of releases from facilities which pose substantial danger to the public health or the environment."
- Section 121(b)(1) states that a remedial action shall be selected "... that is protective of human health and the environment."
- Section 121(d)(2) states the degree of cleanup shall ensure "protection of human health and the environment."

Much of the detail concerning the remediation process is spelled out in Subpart E of the NCP. The basic steps in the remediation process as described in the NCP are:

- **Remedial Site Evaluation (40CFR300.420).** The basic goal of this step is to determine whether remediation is warranted. This step includes the Preliminary Assessment and Site Evaluation. The facility is also scored under the hazard ranking system (HRS) at this point. If the facility score exceeds 28.5, it is placed on the NPL.
- **Remedial Investigation/Feasibility Study (RI/FS) (40CFR300.430).** The purpose of the RI/FS is to assess site

conditions and evaluate alternatives to the extent necessary to select a remedy. The RI assesses the nature and extent of releases of hazardous substances and determines those areas of a site where releases have created damage or the threat of damage to public health or the environment. The FS develops a range of remedial alternatives taking into account the findings of the RI.

- **Remedial Design/Remedial Action/Operation and Maintenance (40CFR300.435).** In this phase, the selected remedy is implemented.

The ERA generally falls within the RI/FS stage. Although the NCP nowhere specifically states that a study termed an "ERA" must be conducted, section 300.430 states the selected remedy must protect human health and the environment over both the short and long term. In discussing the FS in section 430(e)(7)(iii), the NCP sets nine criteria for evaluating remediation alternatives, the first of which is overall protection of human health and the environment. Finally, section 430(f)(i)(A) states that:

> Overall protection of human health and the environment and compliance with ARARs [Applicable or Relevant and Appropriate Requirements] (unless a specific ARAR is waived) are threshold criteria that each alternative must meet in order to be eligible for selection [6].

According to the EPA, compliance with these laws and regulations (as well as numerous other Federal and State laws and regulations) requires an evaluation of site-related ecological effects and the measures necessary to mitigate these effects [4]. The form this evaluation has come to take is the ecological risk assessment.

Evolution of ecological risk assessments in Superfund

Introduction

Despite its current widespread use in the Superfund program, the field of ecological risk assessment is relatively new, complex, and rapidly evolving. As recently as 1989, ERAs were not always an important component of the CERCLA remediation process, particularly in comparison with the assessment of risks to human health [7]. The development of ERA guidance from the EPA has lagged behind that for human health assessments. In part, this reflects the fact that human health risks were the motivating factors in the passage of CERCLA. At this point, formal national guidance for conducting ERAs does not yet exist. As a result, individual EPA regions and the states have developed a varying set of approaches for conducting these studies. Organizations like the DON with sites in all EPA regions have thus had to conduct ERAs in a variable regulatory environment.

A brief history of ERAs in Superfund

The initial focus at Superfund sites was on the analysis and mitigation of human health risks. In 1989, the EPA published its first formal documentation on ERAs [8]. This publication provided background ecological information for site remedial program mangers. At the same time, the EPA's office of Policy Analysis also published a series of studies discussing the nature and extent of ecological threats at Superfund sites, the ecological assessment methods that had been used in the program, and the extent to which ecological concerns had been used as a basis for decision-making at Superfund sites [7, 9–11]. The study examined 52 sites, almost all of which were listed on the NPL. The general findings of the EPA review were as follows:

- The primary ecological resource at risk in most sites was surface water and wetlands. Almost all the sites had contaminants present that are acutely toxic to organisms when present in sufficient concentrations. However, only a small fraction of the sites showed evidence of intense or acute effects, and these effects were generally confined to small areas.

- Considerable variability existed in the approach taken, effort expended, and types of data acquired for these assessments. EPA concluded that without clear policy and guidance, evaluations of ecological threats would continue to be inconsistent, overlook significant impacts or risks, and fail to provide information useful for the purpose of risk management decisions.

- Ecological concerns did not significantly affect remedy selections at over half of the 52 sites.

Partly in response to these findings, the EPA (through its Risk Assessment Forum) initiated a process to develop formal ERA policy and guidance in a manner similar to the approach that had been taken for developing guidance for human health risk assessment.

In 1992, the Risk Assessment Forum published an Agency-wide *Framework for Ecological Risk Assessment* [3]. The *Framework* provides a structure and consistent approach for conducting risk assessments independent of the specific EPA program. It is based on a widely accepted paradigm for human health risk assessment developed in 1983 by the National Research Council [12]. The *Framework* identifies three fundamental steps in conducting an ERA:[2]

- **Problem formulation.** In this step, a preliminary characterization of the exposure and effects at the site is conducted along with other surveys and studies. This information is used to determine assessment endpoints (the ecological values to be protected at the site) and measurement endpoints (a measurable ecological characteristic that is related to the assessment endpoint). Following this, testable hypotheses are developed explaining how the stressors—chemical contaminants at Superfund sites—may affect the ecology.

- **Analysis.** The analysis phase consists of two activities—characterization of exposure and characterization of effects. The former involves determining the spatial and temporal distribution of chemicals of concern and their interaction with the ecosystem. The latter involves determining the impact of chemicals on individuals, populations, and communities.

- **Risk characterization.** This step takes the information developed in the analysis phase to determine the likelihood that exposure to chemical stressors is producing or may produce adverse ecological effects.

Note that the first two steps are the approach that would be taken to address a scientific problem—that is, identifying the question, formulating hypotheses to answer the question, and then designing a data

2. For a good description of the framework, see [13].

sampling (and modeling) plan to address the hypotheses. The additional step in an ERA is the key one of synthesizing the results to produce a risk estimate.

Our analysis of ERAs conducted at DON sites indicates that most follow this general framework. Concern exists, however, that while the framework is an acceptable way to approach ERAs, more specific guidance is required to ensure that technically defensible ERAs are carried out within the framework [14]. That is, a document is required which provides an overall step-by-step process by which an ERA is designed and executed. Such guidance would also presumably allow for a consistent procedure across all EPA regions.

In contrast to ERAs, EPA has provided widely applicable protocols for formal site-specific human health risk assessments [15].[3] Lacking such guidance for ERAs, a variety of guidance documents are utilized in the EPA regions. Recently, the EPA Risk Assessment Forum followed up the publication of the *Framework* with a *Proposed Guidelines for Ecological Risk Assessment* (DRAFT). Although this document expands on a number of topics presented in the *Framework*, notably in its discussion of the treatment of uncertainty in ERAs, it does not provide the level of technical detail that is available in human health risk assessment guidance. The new document has been peer-reviewed but has not yet been formally published by the EPA.

3. There is, however, considerable controversy over the approach used by the EPA to characterize human health risk. See, for example, [16] and [17].

Characteristics of ERAs

Introduction

In this section, we outline in some detail the typical components of an ERA as they are conducted at DON sites under CERCLA. In particular, we focus on the way ecological risk is characterized. ERAs are often complex scientific undertakings. As we discuss later in this section, they are "retrospective" in nature. A spill or release of hazardous waste has occurred and the ERA attempts to determine the actual or potential risk to ecological resources posed by the release. At DON sites, they have usually been motivated by knowledge of an existing source as opposed to the observation of an adverse effect (for example, a fish kill or dead and dying vegetation). To demonstrate risk, ERAs must plausibly relate site contaminants to actual or potential adverse effects on ecological resources. Finally, ERAs must communicate a risk estimate that will support a remedial decision.

Predictive versus retrospective risk assessments

In general, risk assessments can largely be considered **predictive** or **retrospective** [18]. Predictive assessments begin with a proposed new source (for example, introduction of a new chemical or an effluent discharge into surface water) and then proceed to estimate the risks of effects. By contrast, retrospective assessments begin with the existence of a hazardous waste source and then estimate the risks of effects. In the retrospective assessment, some degree of exposure of the ecosystem to the hazardous substance has actually occurred, whereas in the predictive assessment it has not. Retrospective assessments can also be driven by the observation of an effect (for example, a fish kill in a body of water or the declining population of a species) and then attempt to estimate the source. As the above definitions imply, most ecological risk assessments performed under the Superfund program are retrospective in nature.

Most ecological risk assessments conducted at DON Superfund sites are source-driven as opposed to effects-driven. That is, the impetus for performing the assessment is almost always the existence of a site as opposed to observations of significant environmental effects. All the ERAs we reviewed were conducted as part of the SI or RI process and were retrospective in nature. They involved assessing the current impact and potential future risk to the environment of a release that had already occurred.[4]

An ERA associated with assessing the potential risk to the environment of a set of remedial options developed in the feasibility study (FS) would likely have more in common with a predictive assessment. This would be the case where an option involved physical alteration of a habitat (through soil or sediment excavation, for example). We did not review any risk assessments of this type.

What are the components of an ERA?

A general approach for conducting ERAs involves the steps of problem formulation, analysis, and risk characterization. In this section, we describe these steps in more detail as they apply to the source-driven risk assessments typically performed at DON sites.[5] Figure 1 presents a flowchart of the process.

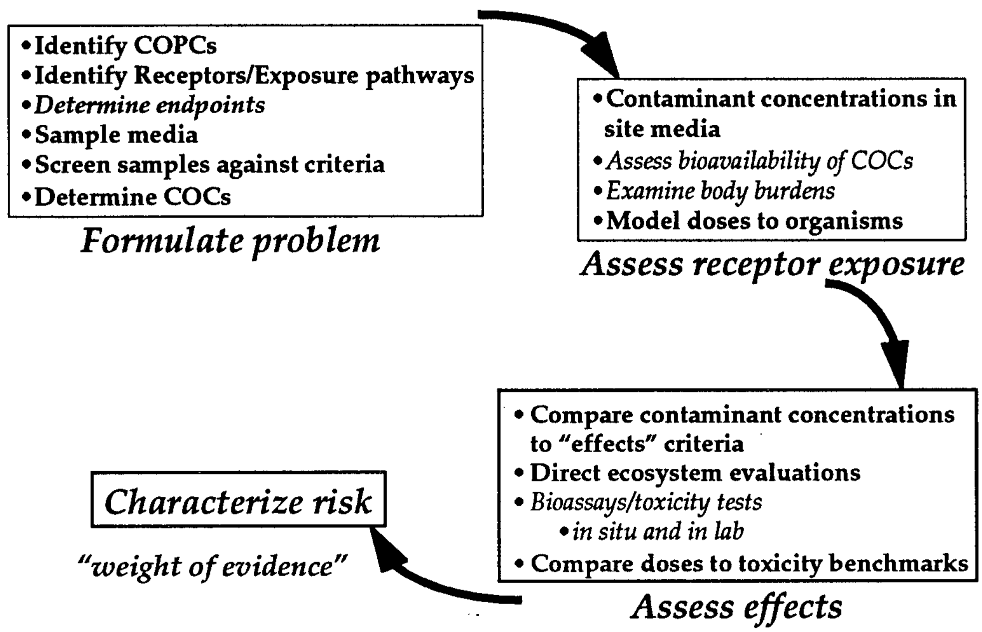
The problem formulation phase involves the following activities:

- **Description of the environmental setting of the site and regions around the site.** This includes noting whether the site is used by any threatened or endangered species and whether it contains ecologically valuable resources such as wetlands and surface waters. For obvious reasons, DON sites frequently contain or are adjacent to wetlands and surface water.

4. Some ecologists consider retrospective assessments to be more of an "impact" or effects" assessment and not a true predictive risk assessment. See, for example, page 123 in [19].

5. Information in this section is taken from [4, 18, 20] and from our analysis of ERAs conducted at DON sites.

Figure 1. Typical components of ERAs conducted at DON sites. Screening-level ERAs may not include components indicated by italics



- **Identification of contaminants of potential concern (COPCs).** These are contaminants known or suspected to exist at the site.

- **Identification of the receptors likely to be exposed to and affected by the COPCs.** Receptors are individual organisms or populations and communities that can be exposed to a contaminant. Of particular concern are species considered threatened or endangered, species considered essential to or indicative of the healthy functioning of a habitat, and species which are commercially valuable. This part of the problem formulation also involves identification of the toxic mechanism associated with each of the contaminants (typically through a literature or database search).

- **Identification of exposure pathways to receptors.** Exposure pathways are the routes by which a contaminant is released from a site and comes into contact with a receptor. For example, receptor exposure can occur through direct contact with contaminated media (dermal, uptake through gills, ingestion) or through the food chain. If an exposure pathway from the site to a receptor does not exist, the contaminant does not pose a threat.

- **Selection of assessment and measurement endpoints.** Based on the preceding information, assessment endpoints are determined for the risk assessment. Assessment endpoints are the ecological values selected for protection. As such, they are the link to the risk management decision which follows the assessment. Examples of assessment endpoints are the survival/maintenance of benthic macro-invertebrate community structure and function, and the survival/maintenance of fish populations. Measurement endpoints are the actual quantities estimated during the ERA that should approximate, represent, or characterize the assessment endpoints. Frequently, the problem formulation phase incorporates the development of a (qualitative) conceptual model that shows the exposure pathways to receptors, and links the measurement endpoints to assessment endpoints.

- **Determination of chemicals of concern.** We include this activity in the problem formulation phase although elements of it can be considered part of the analysis phase. To separate chemicals of actual concern at a specific site from the (usually lengthy) list of COPCs, the contaminated media at a site is sampled, and concentrations are screened against various criteria that have been developed to indicate the existence of potential risk. For example, sediment concentrations are often compared to criteria developed by NOAA [21, 22].[6] A so-called hazard quotient (HQ) is calculated as the ratio of contaminant in the sampled media to its screening criteria. An HQ of one or greater indicates the contaminant could represent risk. For contaminants or media where criteria do not exist, site concentrations can be compared to concentrations at reference sites or regional "background" concentrations.[7]

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6. A good summary of currently available screening criteria can be found in [23].

7. However, choosing an appropriate reference site(s) and calculating regional "background" concentrations can be a difficult analytical problem.

The analysis phase of an ERA consists of two principal activities: analysis of exposure and analysis of effects.

- **Exposure analysis.** In a source-driven assessment, exposure analysis seeks to determine whether and to what extent organisms are exposed to contaminants in various media (soil, sediment, air, water) in such a way as to take up the contaminants. This phase attempts to determine the relationship between COC concentrations in the various media and indicators of exposure in organisms (that is whether the contaminants are *bioavailable* to receptors). A typical indicator of exposure in an organism is concentration of the contaminant in body tissues. Because many sites and adjacent regions may contain large numbers of species, it is not possible to evaluate the exposure of each one. Instead, a limited number are selected for assessment based on the endpoints of concern and specific characteristics of the site under study. Typically, exposure concentrations are measured for organisms at lower trophic levels, and the potential exposure of organisms at higher trophic levels (e.g., carnivores) is assessed through the use of models.

- **Effects analysis.** Effects are the changes in organisms, populations, or communities that can be attributed to exposure to a contaminant. Indicators of toxic effects can include declines in the populations of species, changes in species diversity in a particular ecosystem, or overt toxic injury to organisms. Effects are determined through field surveys in the affected area (usually including comparison with a reference station), evaluations of biomarkers of effects in organisms, toxicity tests, and comparisons of contaminant concentrations to screening levels which could be indicative of the potential for adverse effects. Biomarkers are biochemical or physiological indicators of a toxicological response in an organism. Toxicity tests involve determination of the response of organisms to exposure to contaminated media either on-site or in the laboratory. Onsite exposures usually involve placing selected species in cages to determine their response to the contaminated media—again, in comparison with the response at a reference site.

Alternatively, the contaminated media (for example, river sediment) can be brought back to the lab, and toxicity tests can be run in comparison with clean sediments. Effects that are generally evaluated in these tests include survival, growth, and reproduction. A number of standard tests involving a defined set of organisms has been developed over the years.

The final and key phase of the assessment is risk characterization. In this phase, all the information is examined to determine whether adverse ecological effects are occurring, or will occur, as a result of contamination associated with a site. We discuss this phase in more detail later in this section.

Screening level and in-depth ERAs

As the above description makes clear, ERAs can be large-scale, complex efforts. Because the potential toxicity of sites may not be well known prior to conducting an assessment, a tiered or phased approach to conducting ERAs has been advocated both by the EPA and other organizations such as the U.S. Army's Edgewood Research, Development and Engineering Center [3, 13]. Under this approach, progressively more detailed and complex assessments are conducted if initial studies indicate risk may be present. Typically, the first step is to conduct a "screening-level" assessment. This type of assessment involves limited sampling of contaminated media and calculation of hazard quotients. Models can also be used to determine whether and how the contaminants may move up the food chain and present a potential risk to higher trophic levels such as carnivores. If the screening assessment indicates potential risk to one or more receptors, it is used to develop an in-depth ERA to be conducted as part of the RI/FS process. The in-depth ERA can include the full suite of tests and measurements depicted in figure 1.

Within the RI/FS process itself, it has not been uncommon to have phased ERAs as well. These can occur when a review of a phase I ERA reveals data gaps, unanswered questions, or other problems that the EPA and/or state agencies feel must be addressed (see, for example, the NETC Newport ERA [24]).

Risk characterization

Although quantitative techniques (measurements and models) are used to infer risk, the actual characterization of ecological risk at DON sites has been qualitative with emphasis placed on the following factors:

- Are ecological receptors at the site currently exposed to contaminants at levels capable of causing harm? Does the potential exist for future exposure?
- What types of adverse ecological effects (if any) have been observed? What types may occur based on exposure? What are the types, the extent, and the severity (lethal or chronic) of the effects?
- What are the major uncertainties associated with the assessment?

This information is typically summarized to produce what is called a "weight of evidence" approach to risk characterization. As used by ecological risk assessors, this approach attempts to compensate for uncertainty in risk assessments by compiling as many consistent lines of evidence for ecological harm (or the lack thereof) as the data will support.

In practice, the existence of contaminant concentrations in media exceeding "effects" screening criteria is taken as evidence of potential risk at a site. This risk may be characterized as minimal if no other lines of evidence indicate risk, if the site appears to provide a poor habitat for biota, and if site concentrations are within background or reference levels. On the other hand, the level of risk progressively rises if contaminants are found to be bioavailable; if evidence can be found linking contaminants in organism tissues to site-related contaminants in media; if evidence exists that contaminants are present at levels producing toxic responses; and if direct field observations provide evidence of a stressed population, community, or ecosystem.

The risk characterization phase should provide the evidence of risk to the assessment endpoints or ecological resources of value. As discussed earlier, these endpoints are typically stated in terms of population, community, or ecosystem measures (i.e., maintaining the health of the benthic community) unless the assessment endpoint concerns the protection of an endangered species. Many of the quantitative measures indicating risk, however, are related to exposure or effects on individual organisms. Therefore, the difficult analytical issue in ecological risk assessment is relating these organism-level measurements to the assessment endpoints. This can be done via modeling techniques. As stated in [18],

> although it is a common practice to express the assessment endpoint in terms of a measurement endpoint, it is unrealistic, in general, to assume that any test result represents the response of a population or ecosystem in the field. To make this extrapolation, some model must be applied to either the measurement endpoint or the original test data.

However, as noted in [13],

> The evaluation of the ecological significance of a risk is a process at the very edge of the capability of ecological science. Biological populations are very dynamic and population measures and models are relatively simple compared to the underlying ecological complexity. *Yet it is at the population level that ecological significance must be evaluated* [our italics]...

The only modeling approach we observed in DON ERAs was "food web" modeling. This approach assesses the daily dose of a contaminant that an organism may receive via various pathways. A comparison is made of this dose with doses that can cause a toxic effect on the individual. This approach does not directly model population or community-level effects.

For the most part, the ERAs we reviewed did not use modeling techniques to relate measurements to assessment endpoints. Instead, they summarized the individual quantitative indicators of risk and provided a qualitative judgement as to their significance relative to the assessment endpoints. These qualitative judgements varied from one assessment to another but typically included phrases such as "potential risk," "some risk," "low potential risk," "substantial risk," and others.[8]

8. A summary of risk characterization in all the ERAs reviewed for this study is in appendix D.

A substantial difference exists in risk characterization between human health and ecological risk assessments. In the former case, of course, human health at the individual level is the assessment endpoint of concern. As a result, assessment endpoints do not vary from site to site. Under these circumstances, standard analysis scenarios have been developed to assess, for example, the excess cancer risk to individuals posed by exposure to contaminants at Superfund sites. The resulting risk characterization is quantitative and provides a decision-maker an estimate of the risk as well as potential remediation goals.

We should note that the scenarios, assumptions, and measurements which define the risk to human health at Superfund sites are very controversial [16, 17]. The point here, however, is that the risk estimate coming from an HHRA differs in fundamental ways from that coming from an ERA. As the EPA noted in 1991:

> The science of ecological risk assessment has not evolved to the point where scientists can make standard risk calculations for common risk scenarios, as they often do in human health evaluations at Superfund sites. Risk characterization in ecological assessment is a process of applying professional judgement to determine whether adverse effects are occurring or will occur.... [20].

Data set used in this study

List of installations

In this section, we describe the characteristics of the data set used in this study. We reviewed ERA reports covering 20 installations, including at least one from each of the NAVFAC EFDs/EFAs (table 1). Most of the installations for which we obtained data are listed on the NPL, and six are scheduled to close under BRAC.

Table 1. Summary of facilities for which data was obtained

Facility	EFD/EFA	EPA region	NPL/BRAC[a]	Reference
NCBC Davisville RI	Northern Division	1	NPL; BRAC II	[25, 26]
NSB New London	Northern Division	1	NPL	[27]
NSY Portsmouth	Northern Division	1	NPL	[28]
NC Philadelphia	Northern Division	1	BRAC	[29]
NETC Newport	Northern Division	1	NPL	[24]
NSWC Dahlgren	Chesapeake EFA	3	NPL	[30]
MCB Quantico[b]	Chesapeake EFA	3	NPL	[31]
MCB Camp Lejeune	Atlantic Division	4	NPL	[32–48]
Allegany BL	Atlantic Division	3	NPL	[49, 50]
NWS Yorktown	Atlantic Division	3	NPL	[51]
NSGA Sabana Seca, PR	Atlantic Division	2	NPL	[52]
NAS Cecil Field	Southern Division	4	NPL; BRAC III	[53–56]
NAS Jacksonville	Southern Division	4	NPL	[57]
MCAS Yuma	Southwestern Division	9	NPL	[58]
NWS Concord[b]	Western EFA	9	NPL (Proposed)	[59]
NAS Moffett Field	Western EFA	9	NPL; BRAC II	[60]
NS Treasure Island[b]	Western EFA	9	BRAC III	[61]
Hunters Point Annex	Western EFA	9	NPL; BRAC II	[62, 63]
NAS Whidbey Island	Northwest EFA	10	NPL	[64, 65]
FISC Pearl Harbor	Pacific Division	9	NPL	[66]

a. NPL status from [2].
b. ERA Workplan only.

The scope of the ERAs ranged from investigations of single sites to operable units (generally composed of multiple sites at a single installation) to entire installations. Appendix A describes the scope of each report and provides a detailed list of individual sites. The reports for Marine Corps Base Quantico, Naval Weapons Station Concord, and Naval Station Treasure Island are ERA workplans only. We included them in our data set because although they yield no information on ERA findings, they did provide information on site types, study scopes, and costs.

Summary description of sites

Tables describing characteristics of the individual sites are in appendix B, and tables showing the waste types and chemicals of concern at each site are in appendix C.

Environment types

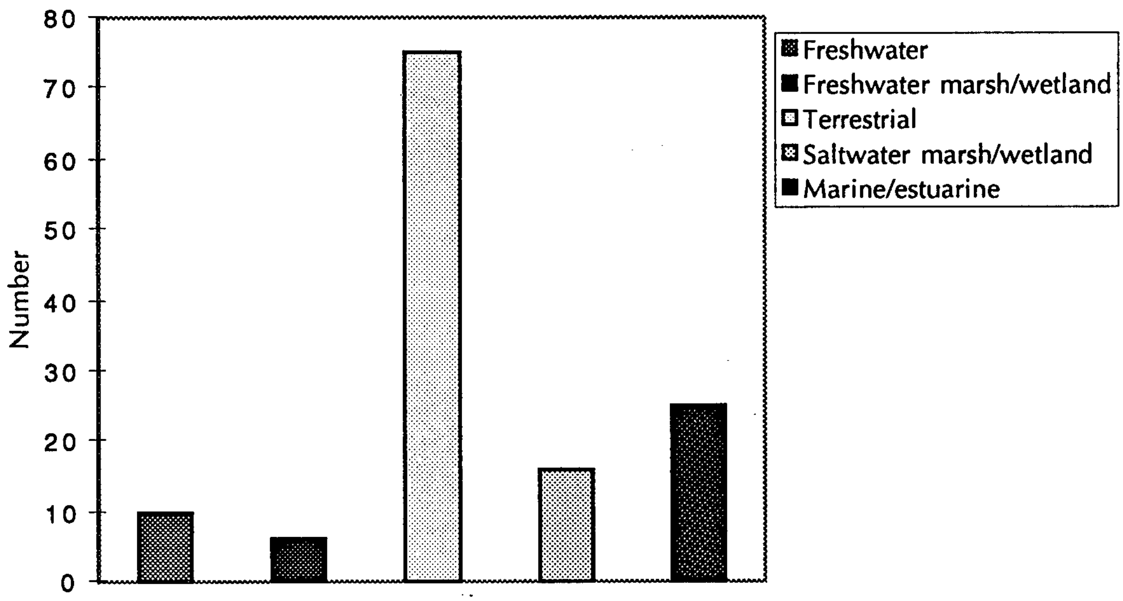
Based on site descriptions in the ERA reports, we classified the environments in which ERAs were conducted into five categories:

- Freshwater
- Freshwater marsh/wetland
- Terrestrial
- Saltwater marsh/wetland
- Marine/estuarine.

In many cases, a site contained more than one of these environment types. Figure 2 shows the number of occurrences of each of these environment types in our data.

The most common environment type is terrestrial because contaminants are almost always initially leaked or disposed of on land, rather than directly into water bodies. Therefore, even in cases in which the primary concern is with impacts on water bodies, the effects of the contaminants on terrestrial habitats in the immediate vicinity of the release must usually be assessed.

Figure 2. Environment types at Navy ERA sites



Of course, Navy installations are usually located adjacent to rivers and bays. Chemical contaminants released at these facilities are often transported into the adjacent water body and end up in bottom sediments. Therefore, the second most common environment type for Navy ERAs is marine/estuarine.

Waste types and chemicals

Figure 3 summarizes the waste types found at the Navy sites we reviewed. A single site often contains more than one type of waste. The most frequently occurring category is "Industrial Wastes." This isn't surprising, because the vast majority of remediation sites are associated with "industrial" type operations at Navy installations. We suspect that this very general category includes, in many cases, the wastes indicated by the other categories in figure 3.

Chemicals of concern at the sites we reviewed are summarized in figure 4. Most sites contain more than one of these classes of chemicals (almost all sites contain metals). This distribution is very similar to that reported by the EPA in an earlier review of ERAs conducted largely at commercial Superfund sites [7].

Figure 3. Waste types

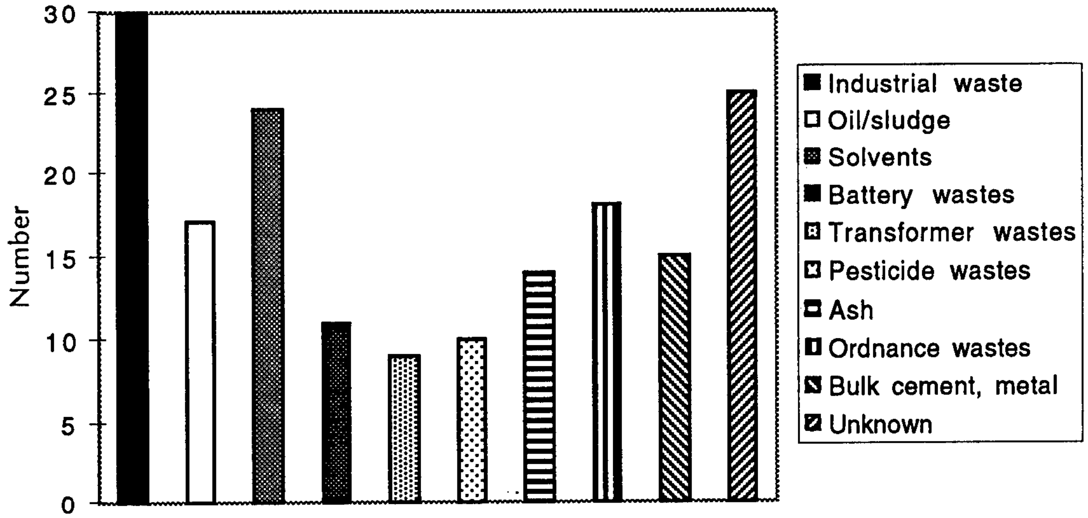
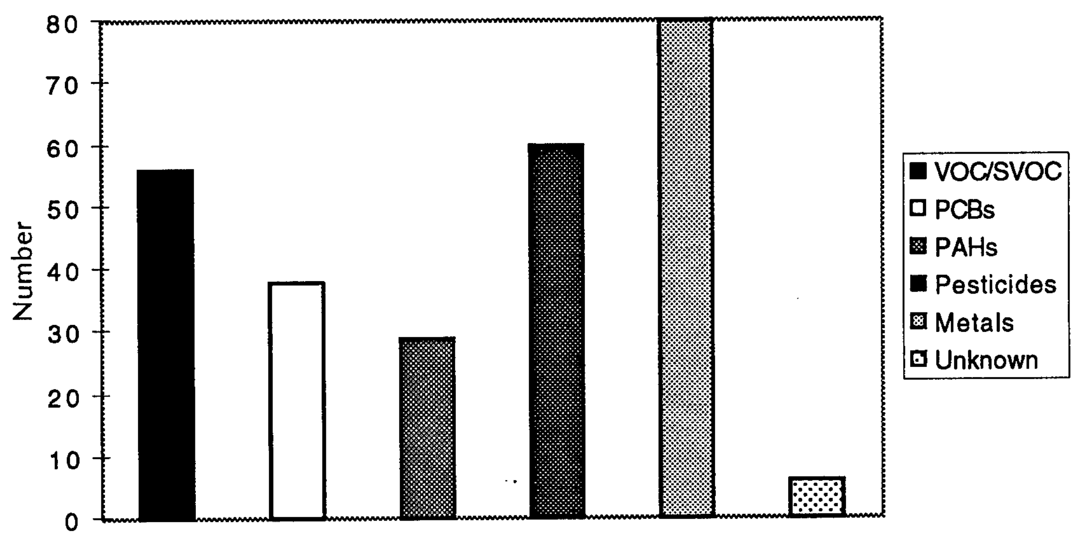


Figure 4. Chemicals of concern



Principal findings

Introduction

In this section, we answer the following questions from the study request:

- Are ecological risk assessments revealing negative ecological effects? Are they affecting remedy selections or cleanup levels?
- How much do ERAs cost?
- Is there duplication of effort across the Navy in studies on effects of contaminants on specific organisms?

The final issue raised in the study request—identification of parameters which could be used to determine when an ERA is appropriate and necessary—will be covered in the final section.

What are ERAs revealing?

Our analysis of ERAs suggests the following:

- Most ERAs have not found significant adverse effects despite the fact that *all* sites have some contaminant levels exceeding various screening criteria indicative of the potential for adverse effects. By significant adverse effects, we mean both evidence of toxicity in site-contaminated media through lab tests and bioassays as well as direct field evidence of ecosystem stress or damage. The lack of field evidence of damage may be surprising in that many of these sites are quite old—typically dating from the 1960s and 1970s (and earlier in some cases).
- The level of risk in our sample is not high. Half of the ERAs indicate minimal or no risk to ecological resources at the sites despite the screening-level exceedances. This is largely because other evidence suggests minimal risk. The remainder indicate

either potential risk or likely risk to ecological resources. This is largely a result of the fact that screening exceedances exist and other evidence suggests risk as well.

- Twenty-seven (34 percent) of the sites for which we examined ERAs have reached the ROD stage. We identified six ERAs which appeared to have had an impact on the remedy selection. In one case (site 16, operable unit 3 at Whidbey Island NAS), the ERA appeared to directly drive the remedy selection.

The following three sections elaborate on these findings.

Exceedances and effects

As discussed earlier, an important step in the ERA is sampling the media, analyzing for contaminants of potential concern, and when detected comparing these concentrations against various screening criteria via computation of hazard quotients. *Every* ERA we examined reported one or more exceedances in at least one of the media under investigation. Thus, by definition, potential risk to the environment was present at every DON site for which an ERA was conducted. However, the rest of the evidence for risk was mixed.

Table 2 shows the relationship between observed exceedances at the sites and other information in the ERAs. The issue of bioavailability is important and can be inferred from certain tests on the contaminated media itself (e.g., total organic content for organics [24]) or directly confirmed through the results of bioassays. The accumulation of contaminants into lower levels of the food chain can be assessed through examination of concentrations found in organism tissues and plant material. The exposure of higher trophic levels to contaminants can be modeled by computing daily intakes for selected organisms and then comparing these values to toxicity reference values (typically obtained from lab studies). Bioassays and toxicity tests can be used to assess the impact of contaminated media on representative organisms. Finally, direct field observations of population/community health and diversity ("population or community effects" column heading in the table) can be conducted. As discussed earlier, all of these tests and procedures attempt to describe the potential risk contaminants pose to ecological resources.

Table 2. Exceedances and other evidence of ecological risk in ERAs reviewed for this study

	Exceedances?	COCs bioavailable?	COCs in tissues?	Assess doses at higher trophic levels?	Doses exceed TRVs?[a]	Toxicity measured?	Pop. or comm. effects?
NSY Portsmouth	Yes	Yes	Yes	Yes	Yes	Yes	No
NETC Newport	Yes	Yes	Yes	Yes	Yes	Yes	No
Davisville Terrestrial	Yes	Yes	N/A	Yes	Yes	N/A	No
Marine	Yes	Yes	Yes	Yes	Yes	Yes	No
NSB New London	Yes	Yes	Yes	Yes	No	Yes	No
NC Philadelphia	Yes	N/A	N/A	Yes	Yes	N/A	N/A
NSWC Dahlgren	Yes	Yes	Yes	Yes	Yes	N/A	No
NWS Yorktown (16)	Yes	N/A	N/A	Yes	Yes	N/A	No
ABL Site 1	Yes	N/A	N/A	No	N/A	N/A	No
Sites 2–5	Yes	N/A	N/A	No	N/A	N/A	No
MCB Lejeune OU 1	Yes	N/A	N/A	Yes	Yes	N/A	N/A
OU 2	Yes	Yes	Yes	Yes	No	N/A	No
OU 4	Yes	N/A	N/A	Yes	Yes	N/A	No
OU 5	Yes	N/A	N/A	Yes	Yes	N/A	N/A
OU 6	Yes	Yes	Yes	Yes	Yes	Yes	No
OU 7	Yes	Yes	Yes	Yes	Yes	N/A	No
OU 8	Yes	N/A	N/A	Yes	Yes	N/A	No
OU 11	Yes	N/A	N/A	Yes	Yes	N/A	No
OU 12	Yes	N/A	N/A	Yes	No	N/A	No
OU 14	Yes	Yes	Yes	Yes	Yes	N/A	No
NAS Jax	Yes	N/A	N/A	Yes	Yes	N/A	No
NAS Cecil Field OU 1	Yes	Yes	Yes	Yes	No	No	No
OU 2	Yes	Yes	Yes	Yes	No	No	No
MCAS Yuma OU2	Yes	N/A	N/A	No	N/A	N/A	No
NWS Concord	Yes	N/A	N/A	No	N/A	N/A	N/A
NS TI HPA Parcel A	Yes	N/A	N/A	No	N/A	N/A	No
Phase IA	Yes	N/A	N/A	No	N/A	N/A	N/A
NAS Moffet Field 1	Yes	Yes	Yes	No	N/A	Yes	Yes*
2	Yes	Yes	Yes	No	N/A	Yes	Yes*
3	Yes	Yes	Yes	No	N/A	Yes	Yes*
NAS Whidbey OU3	Yes	Yes	Yes	Yes	Yes	Yes	Yes*
NAS Whidbey OU4	Yes	Yes	Yes	Yes	No	Yes	N/A
FISC Pearl Harbor	Yes	N/A	N/A	No	N/A	N/A	No

a. TRV is toxicity reference value.

Yes
No
N/A—Component not part of ERA.
Yes*—Unclear if related to DON site COCs.

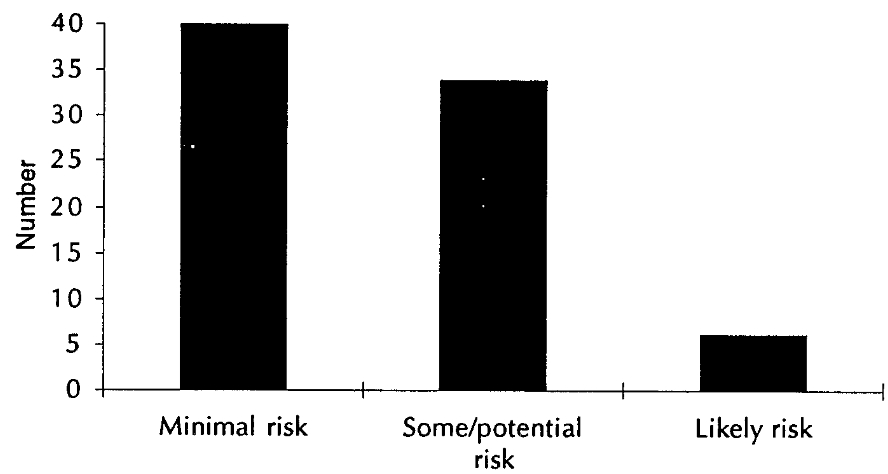
As the last column in table 2 indicates, little direct evidence of adverse population/community impacts exists despite the presence of contaminant exceedances at every DON site. Some ERAs indicated bioavailability of contaminants, potential for accumulation to toxic levels at higher trophic levels, and some direct evidence of toxicity in samples. Examples include ERAs conducted at NETC Newport (marine sediments offshore of McAllister Point landfill), NCBC Davisville (marine sediments offshore of Allen Harbor landfill), and the marine component of the ERA conducted at Portsmouth Naval Shipyard. An ERA which provided field evidence of population/community impacts was the study conducted at Moffet Naval Air Station. In this case, however, it was not obvious that site-related contaminants were the source of the problem. At one NAS Whidbey Island operable unit, several observations of mammal deaths (voles, owls) were recorded. However, the ERA was not able to directly relate these observations to toxic effects from site contaminants.

Level of risk

Figure 5 shows the distribution of estimated risk for the ERAs we reviewed. Recall that the ERAs conducted at DON sites characterized the risk qualitatively. Despite the presence of exceedances, half of the ERAs concluded that minimal risk existed at the sites. The criteria for concluding minimal risk at these sites included lack of suitable habitats and contaminant concentrations within "background" levels. Examples of sites with poor habitats for ecological resources include industrial areas and areas largely covered with pavement. When contaminant levels were within regional background levels, it was assumed that contaminants could not be directly attributed to a source at the site. ERAs concluding that site-related contaminants posed minimal risk generally recommended no further study or no remedial action.

Approximately 40 percent of the sites did indicate some risk or potential future risk. These ERAs revealed contaminant exceedances in some or all site media but left questions about one or more of the following: the source of the contaminants, the bioavailability of the contaminants, transport paths from a source to a receptor, and toxicity at the contamination levels detected. In over half of these assessments, the conclusion of potential or some risk led to a recommendation for further study.

Figure 5. Level of risk at DON sites indicated by ERAs reviewed for this study



A small number of ERAs we reviewed indicated high or significant likelihood of risk to some receptors. The conclusion of likely risk resulted from a "weight of evidence"—that is, numerous indications of risk including many exceedances, clear evidence of pathways from the source to the receptors, evidence of bioaccumulation, and toxicity through several trophic levels. Recall, however, that direct field evidence of adverse population or community effects was not present in most of these studies.

Impact of ERAs on remedy selection

ERAs have had a limited impact to date on remedy selections at the sites in our database which have reached this phase of the remedial process. In part, this reflects the fact (noted earlier) that ERAs have only recently become an important part of the RI/FS process. Many of the sites in our database will reach the record-of-decision phase in FY 1996 or later. It is possible that ERAs could play a more significant role in the future remedy selections than they have to date.

Note that determining the impact of the ERA can be difficult. For example, we do not know how the remedy selection may have changed (if at all) if an ERA had not been conducted. We also do not know the relative weight assigned to HHRA results and other factors relative to ERA results. For example, a site is characterized by an area of contaminated soil. The HHRA and ERA both determine a potential risk exists, and the decision is made to excavate the soil. In these cases, it can be assumed that the HHRA would likely drive the remediation—that is, soil excavation would occur regardless of the ERA result. In addition, HHRAs (and ARARs) provide remediation criteria, whereas ERAs frequently do not. As a result, the ERA may not drive the level of cleanup in the way that an HHRA would.

Also, many DON sites are characterized by groundwater contamination. Groundwater remedies are frequently driven by concerns of potential drinking water contamination. Ecological receptors are not usually a concern in the case of groundwater contamination (unless the groundwater is discharging contaminants into surface water as can be the case with contamination of shallow aquifers).

Table 3 shows the sites in our database which have reached ROD, the selected remedy, and an assessment of whether the ERA contributed to the remedy selection. We attempted to determine the ERA impact on remedy selections in two ways:

- Where possible, we asked NAVFAC remedial program managers (RPMs) if they felt a particular remedy selection had been affected by the ERA results.
- We also examined the detailed RODs and (in some cases) ROD summaries obtained from the EPA RODS database. We looked at the selected remedy and justification to see what criteria had been used.

As indicated in the table, 27 sites in our data sample have had remedies selected. Most of these were described in RODs signed after completion of the RI/FS. In the case of NAS Jacksonville operable unit one, the remedy shown in the table is the alternative recommended in the feasibility study. Also, site 39 at FISC Pearl Harbor went directly from the site investigation phase to the remedial design/remedial action phase. Based on our survey of RPMs and analysis of RODs, it appears that six ERAs had an impact on the remedy selection.

Table 3. Impact of ERA on remedy selection

Installation	OU[a]	Site	Remedy[b]	Impact?	Comment
NAS Cecil Field	1	1	gwm,bm	NO	
NAS Cecil Field	1	2	gwm,bm	NO	
NAS Cecil Field	2	5	gwt,st	NO	
NAS Cecil Field	2	17	gwt,se	NO	
NAS Jacksonville	1	26	se,cap,gwt	NO	Option recommended in FS
NAS Jacksonville	1	27	se,cap,gwt	NO	Option recommended in FS
MCB Camp Lejeune	1	21	se	NO	
MCB Camp Lejeune	1	24	gwm	NO	
MCB Camp Lejeune	1	78	gwt	NO	
MCB Camp Lejeune	2	6	se	YES	ERA supported remedy
MCB Camp Lejeune	2	9	nfa	YES	ERA supported remedy
MCB Camp Lejeune	2	82	gwm	NO	
MCB Camp Lejeune	3	48	nfa	NO	
MCB Camp Lejeune	4	41	ltm	NO	
MCB Camp Lejeune	4	74	ltm	NO	
MCB Camp Lejeune	5	2	se/gwm	YES	ERA supported remedy
MCB Camp Lejeune	11	7	nfa	YES	ERA supported remedy
NSGA Sabana Seca	-	6	cap	NO	
NWS Yorktown	-	16	nfa	YES	ERA supported remedy
NETC Newport	-	1	cap	NO	ERA completed after ROD
NAS Whidbey Island	3	16	sed_r	YES	ERA determined remedy
NAS Whidbey Island	4	39	se	NO	
NAS Whidbey Island	4	41	se	NO	
NAS Whidbey Island	4	44	se	NO	
NAS Whidbey Island	4	48	se	NO	
NAS Whidbey Island	4	49	nfa	NO	
FISC Pearl Harbor		39	se	NO	ERA part of SI

a. OU is operable unit.

b. Remedy selections are identified as follows: gwm = groundwater monitoring. bm = bio-monitoring. gwt = groundwater treatment (various types). se = soil excavation. st = soil treatment *in situ*. nfa = no further action. cap = capping soil or landfill. sed_r = sediment removal.

Cost of ERAs

It is difficult in many cases to separate costs associated with the RI or earlier phases of the remedial process from those associated with the ERA. This is because some of the field sampling program is used for a variety of studies including the ERA. As a result, some of the data we received may not be completely consistent in the way ERA costs were identified.

As might be expected, ERA costs are highly variable depending on the size and scale (site versus operable unit versus installation), assessment level (screening or in-depth), and ecological complexity of the site (e.g., a combination of terrestrial, wetlands, and estuarine environments). Table 4 summarizes the costs of the ERAs we examined. We separated the costs into three groups: less than $100 thousand, between $100 thousand and $1 million, and greater than $1 million. The table also indicates whether the cost was related to a single site, operable unit, collection of sites, or other grouping.

The basic characteristics of the most expensive ERAs include the following:

- In-depth ERAs. Installation-wide screening ERAs can be expensive, however, as the cost for the Philadelphia Naval Complex indicates. In-depth ERAs tend to make extensive use of bioassays and other lab tests. Five of the eight ERAs costing in excess of $100 thousand and all costing in excess of $1 million rely on a variety of bioassays, toxicity tests, and other laboratory work.
- The ERA includes a significant marine/estuarine component. All of the ERAs costing in excess of $1 million have this characteristic.
- The ERA is one in a sequence. At some sites, a number of ERAs were conducted with later ones addressing issues and sampling problems left by the earlier ones. The implication is that there was difficulty satisfying the local EPA region and/or state environmental division.

Table 4. ERA costs at DON sites

Installation	ERA	Cost	Notes
ERAs costing less than $100K			
NAS Cecil Field	OUs 1,2,7,8	$93.3 K	
MCAS Yuma	17 sites	$65 K	
NAB Little Creek[a]	Installation	$63 K	Screening level
MCB Camp Lejeune	OUs 1,2,4,5,6, 7,8,11,12,14	$43 K	Some ERAs still under way
Allegany BL	Sites 1,2,3,4,5	$37.5 K	
NSGA Sabana Seca	Site 6	$35 K	Estimated cost
NAS Oceana[a]	17 sites	$20 K	Qualitative, screening level
NWS Yorktown	Site 16	$3.3 K	15 additional sites in RI
ERAs costing between $100K and $1M			
NWS Concord	3 RASS[b]	$588K	
NSY Portsmouth	Estuary	$500 K	$2.9M for RI. ERA cost approximate
NSB New London	Installation/ estuary	$500 K	
NC Philadelphia	6 sites	$435 K	Screening level
NSWC Dahlgren	8 sites	$275 K	
MCCDC Quantico[a]	Installation	$275 K	Planned effort
NRTF Driver	Site 1	$460 K	Estimate, $198 K awarded to date
NAS Jacksonville	2 sites	$115 K	
ERAs costing more than $1M			
NCBC Davisville	Terrestrial and estuary	$3 M	
NS TI Hunters Point Annex	Installation and estuary	$1.81M	Phase IA complete, Phase IB planned
NETC Newport	2 sites	$1.4 M	
NAS Moffet Field	Installation	$1.29 M	
NS Treasure Island[a]	Installation	$1.18 M	Planned effort

a. Cost data only. ERA not reviewed in this study.
b. RASS is a remedial action subsite.

According to [67], approximately 640 RI/FS are planned for completion from FY 1997 and out at NPL sites alone. An additional 700 RI/FS at non-NPL and BRAC sites and 195 Resource Conservation and Recovery Act (RCRA) facility investigations (RFI) remain to be completed over the same time period as well. ERAs conducted as part of these studies will vary in scope and cost depending on the factors described above. The data we have suggest that an in-depth ERA covering a moderately complex environment will cost on the order of $100 thousand or more. The DON may have a large bill yet to come on these assessments.

We need to emphasize that we did not request details on the costs of laboratory work, field work, synthesis of results, or report preparation for the purposes of this study. We do not know what the exact cost breakout of an ERA would reveal.

Duplication of effort at ERAs

ASN(I&E) asked CNA to discuss potential duplication of effort across the Navy concerning studies on effects of contaminants on specific organisms. The issue involves the use of bioassays and toxicity tests. The tests are used in some ERAs to provide additional evidence about potential ecological risk. Of the ERAs we examined, bioassays/toxicity tests were employed in just over 25 percent. These tests will be used in all of the planned ERAs for which we received work plans (MCCDC Quantico, NS Treasure Island, NS Treasure Island–Hunters Point Annex).

In general, ERAs conducted at DON sites use available information in databases and the scientific literature to characterize the toxicity of specific contaminants to organisms. For example, they do not engage in basic research identifying the specific response of an organism to varying doses of a particular chemical. In our data sample, only the ERA at NSY Portsmouth conducted this type of test.

Bioassays at DON sites investigated the toxicity of site-specific *mixtures* of contaminants in sediment, soil, and water. These mixtures and the characteristics of the media vary from site to site. There is not a large amount of data in the scientific literature about the toxicity of mixtures of contaminants (are the individual effects additive, synergistic, antagonistic). Given a requirement to assess site-specific toxicity, duplication of effort does not appear to be a major issue.

A different duplication issue is repeated ERAs and ecological studies at the same site. In some cases, the second ERA resamples the area of interest and conducts a similar series of tests as were performed in the first ERA. We observed this scenario at the following installations: NETC Newport, NCBC Davisville, NWS Concord, and the planned efforts at NS Treasure Island and Hunters Point Annex. Part of the explanation for this may be a "learning-curve" issue. Because ERAs are a relatively new process, a certain amount of learning and interaction between the EPA region/state and the risk assessors was required early on [68]. Once the requirements are understood, repeated ERAs should become much less common. In other cases, successive ERAs represent use of a phased or tiered approach to conducting these assessments.

Discussion and recommendations

Discussion of risk findings

All the ERAs we examined began with the finding that the potential for ecological risk existed because contaminants exceeded screening levels at some locations for some media. Further investigation revealed either that the risk was "minimal" (for reasons discussed earlier), or that it was possible or likely. In most cases, ERAs did not go much further than the "possibly some risk" to assessment endpoints level of precision. This does not necessarily reflect a problem with the conduct of the individual ERAs. Rather, we think it reflects the fact that the science of ecological risk assessment is limited in its capability to provide more precise risk estimates to typical assessment endpoints.

Perhaps general qualitative findings are sufficient information to allow remediation decision-makers to weigh ecological considerations in deciding if and how to remediate a site. Our point is simply that the current state of the art in retrospective ecological risk assessment as applied at DON sites does not provide quantitative estimates of risk (i.e., probabilities and magnitudes) to assessment endpoints in most cases [20].

Recommendations

Based on our findings, we provide the following three observations and recommendations.

First, a realistic appreciation of the limits of ERAs in determining risks and supporting remediation decisions is required. ERAs as presently conducted for DON can provide quantitative estimates of risk to individual organisms, but provide only qualitative risk estimates to the populations, communities, or ecosystems. Given the limitations in

ERAs, DON should not expect that expanded ERA scopes or additional study will lead to a more precisely quantified risk. In addition, the way risk is characterized in ERAs may make it easy for risk managers to default to other criteria such as ARARs.

Second, DON (perhaps in conjunction with the other services) should develop guidance or policy for how to proceed in cases in which exceedances are found but other compelling evidence of ecological risk (such as visible evidence of a stressed or damaged ecosystem) is lacking. Screening exceedances have always been found. As a result, using a tiered or phased approach as is now advocated in guidance will almost always lead to more study. And as we discovered, the resulting risk estimate is still qualitative.

Third, observational criteria could be applied with regard to habitat suitability or visible effects before investing large amounts of effort in ERAs. We saw instances in which a complete ERA was performed, only to conclude with a statement that the habitat is unsuitable for various other reasons, so there is no point in cleaning it up.[9] We note that most ERAs did not reveal evidence of stressed or damaged communities and ecosystems despite the presence of contaminant exceedances.

Finally, we emphasize that only DON ERAs were reviewed for this study. At this time, we do not know if our findings are similar to those that would be found in a review of ERAs conducted for other services and federal agencies. Examining these ERAs would be useful to place our results in the context of the overall CERCLA program.

9. It has been pointed out, however, that the Navy has not had much success in two EPA regions using this line of argument [68, 69].

Appendix A: Data set

Table 5 lists all ERA reports reviewed in this study, and shows the scope of each report.

Table 5. List of ERA reports reviewed

Report number	Installation	Operable unit	Site	Reference
1	NCBC Davisville:	Terrestrial	Several watersheds	[25]
2	NCBC Davisville:	Marine	Allan Harbor Landfill	[26]
			Calf Pasture Point	
3	NSB New London		Facility-wide	[27]
4	NSY Portsmouth		Facility-wide	[28]
5	NC Philadelphia	Marine	Facility-wide	[29]
		Terrestrial	RCRA M-20	
			1	
			2	
			4	
			5	
			EBS 5	
			EBS 7	
6	NETC Newport		McAllister Pt. Landfill	[24]
7	NSWC Dahlgren		2	[30]
			9	
			10	
			12	
			17	
			19	
			25	
			29	
8	MCB Quantico[a]		Facility-wide	[31]
9	MCB Camp Lejeune	1	21	[32]
			24	
			78	
10	MCB Camp Lejeune	2	6	
			9	[33]

Table 5. List of ERA reports reviewed (continued)

Report number	Installation	Operable unit	Site	Reference
			82	
11	MCB Camp Lejeune	4	41	[34]
			74	
12	MCB Camp Lejeune	5	2	[35]
13	MCB Camp Lejeune	6	36	[36]
14	MCB Camp Lejeune	6	43	[37]
15	MCB Camp Lejeune	6	44	[38]
16	MCB Camp Lejeune	6	54	[39]
17	MCB Camp Lejeune	6	86	[40]
18	MCB Camp Lejeune	7	1	[41]
19	MCB Camp Lejeune	7	28	[42]
20	MCB Camp Lejeune	7	30	[43]
21	MCB Camp Lejeune	8	16	[44]
22	MCB Camp Lejeune	11	7	[45]
23	MCB Camp Lejeune	11	80	[46]
24	MCB Camp Lejeune	12	3	[47]
25	MCB Camp Lejeune	14	69	[48]
26	Allegany Ballistics Laboratory		1	[49]
27	Allegany Ballistics Laboratory		2	[50]
			3	
			4	
			5	
28	NWS Yorktown		16	[51]
30	NSGA Sabana Seca		6	[52]
31	NAS Cecil Field	1	1	[53, 54]
			2	
32	NAS Cecil Field	2	5	[55, 56]
			17	
33	NAS Jacksonville	1	26	[57]
			27	
34	MCAS Yuma	2	CAOC 1[b]	[58]
			COAC 2	
			COAC 3	
			CAOC 4	
			CAOC 5	
			CAOC 6	
			CAOC 7	
			CAOC 8	

Table 5. List of ERA reports reviewed (continued)

Report number	Installation	Operable unit	Site	Reference
			CAOC 9	
			CAOC 10	
			CAOC 11	
			CAOC 12	
			CAOC 13	
			CAOC 14	
			CAOC 15	
			CAOC 16	
			CAOC 17	
35	NWS Concord[a]	RASS[c] 1	4	[59]
			5	
		RASS 2	3	
		RASS 3	25	
			26	
		RASS 4	6	
36	Moffett Federal Airfield		North channel	[60]
			Diked marshes	
			Retention ponds	
37	NS Treasure Island[a]		Facility-wide	[61]
38	Hunters Pt. Annex		Parcels A-E (combined into one)	[62, 63]
39	NAS Whidbey Island	3	Area 16, 31	[64]
40	NAS Whidbey Island	4	Area 39, 41, 44, 48, 49	[65]
41	FISC Pearl Harbor		39	[66]

a. Workplan only.
b. CERCLA area of concern.
c. Remedial Action Subsite; analogous to "Operable Unit."

Some of the reports listed above cover entire installations, with no breakdown into Operable Units or sites (i.e., NSB New London, NSY Portsmouth). Some reports cover single operable units at a facility (i.e., the two NAS Cecil Field reports, some of the Camp Lejeune reports) or multiple operable units at a facility (i.e., NWS Concord). Other reports cover single sites (i.e., some of the Camp Lejeune reports), and others cover multiple sites at a facility (i.e., NSWC Dahlgren, MCAS Yuma, and some of the Camp LeJeune reports). Finally, some reports cover specific types of environments at a facility (i.e., NCBC Davisville, NSY Philadelphia).

Appendix B: Site descriptions

This appendix presents tables which summarize key characteristics of the individual sites reviewed in this study. We classified all environments into five categories:

- Freshwater (F)
- Freshwater marsh/wetland (FM)
- Terrestrial (T)
- Saltwater marsh/wetland (SM)
- Marine/estuarine (M).

A single site may contain more than one environment type.

Many of the ecological risk assessment reports we received were one or more chapters taken out of a larger RI report. In the large majority of these cases, we were not given the rest of the report. Therefore, in a few cases we could not determine site uses or characteristics.

Table 6. NCBC Davisville

Site label	Usage	Environment: Description	Environment: Classification
Allen Harbor	Landfill	Estuary with marsh, wetland	M SM
Calf Pasture Point	Adjacent to landfill; Usage unknown	Estuary	M
Terrestrial Watersheds	Landfill; other disposal areas for battery acid, solvents, transformer oil.	Mostly wetland	F FM

Table 7. NSB New London sites

Site label	Usage	Environment: Description	Environment: Classification
Base, includes Goss Cove landfill	Landfill	Thames River	M

Table 8. NSY Portsmouth sites

Site label	Usage	Environment: Description	Environment: Classification
Estuary[a]	Landfill, USTs, Industrial waste outfalls	Estuary	M SM

a. Multiple sites within NSY included landfills, disposal areas, and others. The ERA reviewed covered the estuarine portion of the environment, i.e., impacts on the adjacent water bodies.

Table 9. Naval complex Philadelphia sites

Site label	Usage	Environment: Description	Environment: Classification
RCRA M-20	Pistol range	Trees, brush	T
IR Site 1	Landfill	Weedy fields, open ground, shoreline	T F
IR Site 2	Landfill	Weedy fields, open ground, shoreline	T F
IR Site 4	Landfill, incinerator disposal area	Industrial area, open, shoreline	T F
IR Site 5	Landfill, incinerator disposal area	Industrial area, open, shoreline	T F
EBS Site 5	Catapult, airport runway	Open fields, paved areas	T
EBS Site 7	Catapult, airport runway	Open fields, paved areas	T
Marine	N/A	Rivers	F

Table 10. NETC Newport sites

Site label	Usage	Environment: Description	Environment: Classification
McAllister Point[a]	Landfill	Vegetated areas, intertidal, pelagic	T M

a. The ERA reviewed for this study covered estuarine areas adjacent to the landfill.

Table 11. NSWC Dahlgren sites

Site label	Usage	Environment: Description	Environment: Classification
Site 2	Ordnance burial area	Sand & gravel; drains to marsh	T
Site 9	Disposal burn area	Grasses, trees	T
Site 10	Formed by road construction	Man-made pond	F
Site 12	Chemical burn area	Mostly bare dirt	T
Site 17	Sanitary landfill	Grasses	T
Site 19	Transformer drainage area	Gravel and pavement; heavily developed	T
Site 25	Pesticide rinse area	Pavement and lawns	T
Site 29	Battery service area	Mostly paved over	T

Table 12. MCB Quantico sites[a]

Site label	Usage	Environment: Description	Environment: Classification
Installation-wide	Area of interest is landfill	Adjacent to Potomac River	M

a. Workplan only; ERA yet to be conducted.

Table 13. MCB Camp Lejeune sites

Site label	Usage	Environment: Description	Environment: Classification
OU 1, Site 21	Industrial	Paved, grass wooded	T
OU 1, Site 24	Industrial	Wooded, drains to creek	T M
OU 1, Site 78	Industrial	Mostly paved, drains to creek	T M
OU 2, Site 6	Storage lot	Dirt and creeks	T M
OU 2, Site 9	Fire training pit	Mostly paved, drains to creek	T M
OU 2, Site 82	Dumpsite	Wooded, borders creek	T M
OU 4, Site 41	Landfill	Wooded and wet-land	SM
OU 4, Site 74	Mess hall grease disposal pit	Wooded	T M
OU 5, Site 2	Former storage area	Grass, drains into creek	T M
OU 6, Site 36	Dump area	Borders tidal creek	T M SM
OU 6, Site 43	Dump	Two creeks	M
OU 6, Site 44	Dump	Adjacent to creek	T SM
OU 6, Site 54	Fire training burn pit	Open fields, grass	T M
OU 6, Site 86	Industrial area	Mowed grass and asphalt	T
OU 7, Site 1	Liquids disposal area	Unknown	T
OU 7, Site 28	Burn dump	Marsh, grass, trees, creek	T SM M
OU 7, Site 30	Fuel tank sludge area	Trees, near 2 creeks	T M
OU 8, Site 16	Burn dump	Wooded with creek	T M
OU 11, Site 7	Dump	Forested, with wetland	T SM

Table 13. MCB Camp Lejeune sites (continued)

Site label	Usage	Environment	
		Description	Classification
OU 11, Site 80	Metal work, wash-down, painting	Forest and open areas	T
OU 12, Site 3	Old creosote plant	Forest and open area	T
Ou 14, Site 69	Rifle range chemical dump	Wooded, wetland (borders New River)	T SM M

Table 14. Allegany Ballistic Lab sites

Site label	Usage	Environment	
		Description	Classification
Site 1	Waste disposal pits; burning ground	Grassy areas; forested areas, flood plain	T F
Site 2	Burning ground	Grassy area	T
Site 3	Burning ground	Grassy, buildings	T
Site 4	Waste photo developing solution disposal pits	Grassy, buildings	T
Site 5	Landfill	Grassy, shrubs, forested area	T

Table 15. NWS Yorktown sites

Site label	Usage	Environment	
		Description	Classification
Site 16	Unknown	Open area; mixed forest; upland forest	T M FM SM

Table 16. NSGA Sabana Seca sites

Site label	Usage	Environment	
		Description	Classification
Site 6	Pesticide control shop	Grasses, shrubs	T

Table 17. NAS Cecil Field sites

Site label	Usage	Environment	
		Description	Classification
OU 1, Site 1	Landfill (older)	Mostly wetland	FM, T
OU 1, Site 2	Landfill (more recent)	Grass and trees; wetland	FM, T
OU 2, Site 5	Oil disposal pit	Wetland and wooded with creek	FM, T
OU 2, Site 17	Oil sludge disposal pit	Grasses and trees	T

Table 18. NAS Jacksonville sites

Site label	Usage	Environment	
		Description	Classification
OU 1, Site 26	Former landfill	Field; drains into St. Johns River	M T
OU 1, Site 27	Former transformer storage area	Field; drains into St. Johns River	M T

Table 19. MCAS Yuma, OU 2, sites

Site label	Usage	Environment	
		Description	Classification
Area 1	10′ strip around runway	Mostly paved	T
Area 2	Industrial area	Buildings/paved	T
Area 3	Industrial area: auto hobby shop	Buildings/paved	T
Area 4	Unknown	Trees and bushes in industrial area	T
Area 5	Unknown	Bushes	T
Area 6	Housing area	Housing	T
Area 7	Ballfield, taxiway	Some grass, some paved	T
Area 8	Housing	Much paved roads	T
Area 9	Unknown	Light vegetation (10% cover)	T
Area 10	Unknown	Light vegetation (10% cover)	T
Area 11	Scrap metal burial area (long ago)	Unknown	T
Area 12	Near flight line	Light vegetation (10% cover)	T
Area 13	Near flight line	Paved	T
Area 14	Unknown	Grasses, weeds	T
Area 15	Fuel farm	Bare soil; highly industrial area	T
Area 16	2 former USTs; highly industrial	Paved	T
Area 17	Industrial	Paved	T

Table 20. NWS Concord sites

Site label	Usage	Environment	
		Description	Classification
RASS 1, Site 4	Industrial	Mostly tidal marsh	SM T
RASS 1, Site 5	Industrial	Mostly tidal marsh	SM T
RASS 2	Industrial	Mostly tidal marsh	SM T
RASS 3, Site 25	Industrial	Upland grasses	F T
RASS 3, Site 26	Industrial	Upland grasses	F T
RASS 4	Industrial	Grassland, coastal shrubs	FM T

Table 21. Moffett Federal Airfield sites

Site label	Usage	Environment	
		Description	Classification
North channel	USTs, sumps for waste oils, solvents	Tidal marsh	SM
East and west diked marshes	USTs, sumps for waste oils, solvents	Tidal marsh	SM
Storm water retention ponds	USTs, sumps for waste oils, solvents	Various; wetland areas of primary concern	SM

Table 22. NS Treasure Island sites

Site label	Usage	Environment	
		Description	Classification
Installation-wide	Housing; administrative facilities	Man-made island in San Francisco Bay, estuarine	M

Table 23. NS Hunters Point Annex sites[a]

Site label	Usage	Environment: Description	Environment: Classification
Parcels A-E (combined into one)	Shipyard, ship repair	Industrial, residential, fields, salt marsh, estuarine	T SM M

a. Planned Phase IB ERA will also examine marine waters adjacent to the facility.

Table 24. NAS Whidbey Island sites

Site label	Usage	Environment: Description	Environment: Classification
OU 3, Area 16	Runway ditches	Grass, forest, freshwater stream, wetland, tidal flats	F FM T SM
OU 3, Area 31	Fire school	Grass, brushland, sparse vegetation	T
OU 4, Area 39	Areas adjacent to a building	Highly developed area; borders marine waters	M
OU 4, Area 41	Rock seawall	Highly developed area; borders marine waters	M
OU 4, Area 44	Paved vehicle compound	Highly developed area; borders marine waters	M
OU 4, Area 48/9	Unimproved	Open field; borders marine waters	T M

Table 25. FISC Pearl Harbor

Site label	Usage	Environment: Description	Environment: Classification
39	Chemical storage area	Buildings, paved	T

Appendix C: Wastes/chemicals at Navy sites

Table 26 shows the types of wastes found at the Navy sites reviewed in this study. The category labeled "Ordnance Wastes" refers to spent ordnance casings and wastes associated with the manufacture or destruction of ordnance. It does not include live ordnance. Table 27 shows the chemicals of concern (COCs) identified at the sites reviewed in this study.

Table 26. Waste types at Navy sites

	Industrial wastes	Oil/oily sludge	Solvents	Battery wastes	Transformer wastes	Pesticide wastes	Ash	Ordnance wastes	Cement, metal bulk	Unknown/ other
Davisville AH	x		x	x	x					
Davisville CPP	x		x	x	x					
Davisville Terr.	x		x	x	x					
New London	x									
Portsmouth	x	x	x	x	x					
Philadelphia Marine	x						x	x	x	
Philadelphia M-20	x						x	x	x	
Philadelphia Site 1	x						x	x	x	
Philadelphia Site 2	x						x	x	x	
Philadelphia Site 4	x						x	x	x	
Philadelphia Site 5	x						x	x	x	
Philadelphia EBS 5	x						x	x	x	
Philadelphia EBS 7	x						x	x	x	
Newport	x	x			x		x			
Dahlgren Site 2						x		x	x	
Dahlgren Site 9	x						x			
Dahlgren Site 10										x
Dahlgren Site 12								x		
Dahlgren Site 17	x								x	
Dahlgren Site 19					x					
Dahlgren Site 25						x				
Dahlgren Site 29				x						
Quantico										x

Table 26. Waste types at Navy sites (continued)

	Industrial wastes	Oil/oily sludge	Solvents	Battery wastes	Transformer wastes	Pesticide wastes	Ash	Ordnance wastes	Cement, metal bulk	Unknown/ other
Lejeune OU1, Site 21	x									
Lejeune OU1, Site 24	x									
Lejeune OU1, Site 78	x									
Lejeune OU2, Site 6		x						x		
Lejeune OU2, Site 9		x						x		
Lejeune OU2, Site 82		x						x		
Lejeune OU4, Site 41	x					x				
Lejeune OU4, Site 74	x					x				
Lejeune OU5, Site 2										x
Lejeune OU6, Site 36										x
Lejeune OU6, Site 43										x
Lejeune OU6, Site 44										x
Lejeune OU6, Site 54										x
Lejeune OU6, Site 86										x
Lejeune OU7, Site 1										x
Lejeune OU7, Site 28										x
Lejeune OU7, Site 30										x
Lejeune OU8, Site 16	x						x			
Lejeune OU11, Site 7			x							
Lejeune OU11, Site 80			x							
Lejeune OU12, Site 3										x
Lejeune OU14, Site 69			x							
Allegany Site 1			x				x	x		
Allegany Site 2							x	x		
Allegany Site 3							x	x		
Allegany Site 4			x							
Allegany Site 5	x								x	
Yorktown Site 16			x	x	x	x				
Sabana Seca Site 6						x				
Cecil OU1, Site 1	x		x							
Cecil OU1, Site 2	x		x							
Cecil OU2, Site 5		x	x							
Cecil OU2, Site 17		x	x							
JAX OU1, Site 26	x	x	x						x	
JAX OU1, Site 27					x				x	
Yuma CAOC 1		x								
Yuma CAOC 2										x
Yuma CAOC 3		x	x	x						
Yuma CAOC 4									x	
Yuma CAOC 5		x	x							

Table 26. Waste types at Navy sites (continued)

	Industrial wastes	Oil/oily sludge	Solvents	Battery wastes	Transformer wastes	Pesticide wastes	Ash	Ordnance wastes	Cement, metal bulk	Unknown/ other
Yuma CAOC 6	x									
Yuma CAOC 7										x
Yuma CAOC 8	x								x	
Yuma CAOC 9	x									
Yuma CAOC 10								x		
Yuma CAOC 11										x
Yuma CAOC 12										x
Yuma CAOC 13								x		
Yuma CAOC 14		x	x							
Yuma CAOC 15		x								
Yuma CAOC 16			x							
Yuma CAOC 17										x
Concord RASS 1, Site 4										x
Concord RASS 1, Site 5										x
Concord RASS 2, Site 3										x
Concord RASS 3, Site 25										x
Concord RASS 3, Site 26										x
Concord RASS 4, Site 6										x
Moffett North Channel		x	x	x		x				
Moffett Diked Marsh		x	x	x		x				
Moffett Retention Pond		x	x	x		x				
Treasure Island										x
Hunters Point	x	x	x	x	x					
Whidbey OU3, Site 16		x								
Whidbey OU3, Site 31							x			
Whidbey OU4, Site 41										x
Whidbey OU4, Site 44										x
Whidbey OU4, Site 48/9										x
Pearl Harbor Site 39			x			x				

Table 27. COCs at Navy sites

	SVOCs/VOCs	PCBs	PAHs	Pesticides	Metals	Other
Davisville Allen Harbor	x	x	x	x	x	
Davisville Calf Past. Pt.	x	x	x	x	x	
Davisville Watersheds	x	x	x	x	x	
New London	x	x	x	x	x	
Portsmouth		x	x		x	
Philadelphia Marine					x	
Philadelphia Site M-20					x	
Philadelphia Site 1					x	
Philadelphia Site 2					x	
Philadelphia Site 4					x	
Philadelphia Site 5					x	
Philadelphia Site EBS 5					x	
Philadelphia Site EBS 7					x	
Newport		x	x	x	x	
Dahlgren Site 2	x			x	x	
Dahlgren Site 9	x		x	x	x	
Dahlgren Site 10	x				x	
Dahlgren Site 12				x	x	
Dahlgren Site 17	x		x	x	x	
Dahlgren Site 19				x	x	
Dahlgren Site 25	x		x	x	x	
Dahlgren Site 29				x	x	
Quantico						x
Lejeune OU1, Site 21	x	x	x	x	x	
Lejeune OU1, Site 24	x	x	x	x	x	
Lejeune OU1, Site 78	x	x	x	x	x	
Lejeune OU2, Site 6	x	x	x	x	x	
Lejeune OU2, Site 9	x	x	x	x	x	
Lejeune OU2, Site 82	x	x	x	x	x	
Lejeune OU4, Site 41	x			x	x	
Lejeune OU4, Site 74	x			x	x	
Lejeune OU5, Site 2		x		x	x	
Lejeune OU6, Site 36	x	x	x	x	x	
Lejeune OU6, Site 43	x	x		x	x	
Lejeune OU6, Site 44	x	x	x	x	x	
Lejeune OU6, Site 54	x				x	
Lejeune OU6, Site 86	x			x	x	
Lejeune OU7, Site 1	x			x	x	

Table 27. COCs at Navy sites (continued)

	SVOCs/VOCs	PCBs	PAHs	Pesticides	Metals	Other
Lejeune OU7, Site 28	x	x	x	x	x	
Lejeune OU7, Site 30					x	
Lejeune OU8, Site 16	x	x		x	x	
Lejeune OU11, Site 7	x	x	x	x	x	
Lejeune OU11, Site 80	x			x	x	
Lejeune OU12, Site 3	x				x	
Lejeune OU14, Site 69				x	x	
Allegany Ballistics Lab Site 1	x				x	
Allegany Ballistics Lab Site 2	x				x	
Allegany Ballistics Lab Site 3	x				x	
Allegany Ballistics Lab Site 4	x				x	
Allegany Ballistics Lab Site 5	x			x	x	
Yorktown Site 16	x	x		x	x	
Sabana Seca Site 6				x	x	
Cecil OU1, Site 1	x	x		x	x	
Cecil OU1, Site 2	x	x		x	x	
Cecil OU2, Site 5	x	x		x	x	
Cecil OU2, Site 17	x	x		x	x	
JAX Site 26	x				x	
JAX Site 27		x				
Yuma CAOC 1			x		x	
Yuma CAOC 2	x				x	
Yuma CAOC 3	x			x	x	
Yuma CAOC 4					x	
Yuma CAOC 5	x			x	x	
Yuma CAOC 6	x			x	x	
Yuma CAOC 7	x	x		x	x	
Yuma CAOC 8	x	x		x	x	
Yuma CAOC 9	x	x		x	x	
Yuma CAOC 10	x		x	x	x	
Yuma CAOC 11						x
Yuma CAOC 12						x
Yuma CAOC 13	x			x	x	
Yuma CAOC 14	x			x	x	
Yuma CAOC 15						x
Yuma CAOC 16	x			x	x	
Yuma CAOC 17	x			x	x	
Concord RASS 1, Site 4	x	x	x	x	x	
Concord RASS 1, Site 5	x	x	x	x	x	

Table 27. COCs at Navy sites (continued)

	SVOCs/VOCs	PCBs	PAHs	Pesticides	Metals	Other
Concord RASS 2, Site 3	x	x	x	x	x	
Concord RASS 3, Site 25						
Concord RASS 3, Site 26	x	x	x	x	x	
Concord RASS 4, Site 6	x	x	x	x	x	
Moffett North Channel		x	x	x	x	
Moffett Diked Marshes		x	x	x	x	
Moffett Retention Ponds		x	x	x	x	
Treasure Island		x		x	x	
Hunters Point Annex		x		x	x	
Whidbey OU3, Site 16				x	x	
Whidbey OU3, Site 31	x				x	
Whidbey OU4, Site 41		x	x	x	x	
Whidbey OU4, Site 44		x	x	x	x	
Whidbey OU4, Site 48/9	x	x	x	x	x	
Pearl Harbor Site 39				x		

Appendix D: ERA conclusions

This appendix presents the conclusions reached by each of the ERA reports we reviewed. The quotes are taken directly from the conclusions sections of the various reports, and are presented just as they were in the original reports. Some of the ERAs presented separate conclusions for each site or operable unit; others simply presented general conclusions for the entire facility or collection of sites. Several reports broke conclusions out by habitat type (aquatic or terrestrial). In the case of Yuma, we summarized the conclusions for all 17 sites with a single finding. The overall ecological risk for the site (as illustrated in figure 5) is shown in parentheses.

NCBC Davisville: Marine (likely)

"Hence it is concluded that the Allen Harbor landfill represents a stressor to indigenous biological communities in the immediate vicinity of the landfill, particularly the southern and northern intertidal areas."

NCBC Davisville: Terrestrial (potential)

"...sites in some watersheds are associated with low or de minimis risk to ecological receptors. In other watersheds, exposure risks associated with various media are potentially elevated, and individual site decision making should incorporate further more detailed apportioning of risk...."

NSB New London

Thames River (potential)

"Therefore, there is some evidence that metals concentrations in sediment are affecting the benthic community in the Thames River. However, these effects may be due to other factors and not attributable to the subase."

"The results of this assessment indicate that, in the Thames River, there may be potential risk to benthic invertebrates."

Goss Cove (potential)

"This assessment predicts potential risks to aquatic receptors and benthic invertebrates inside Goss Cove...."

NSY Portsmouth (potential)

"The occurrence of ecological effects observed in the estuarine study were generally indicative of low-level risks associated with chronic exposure to chemical stressors in the estuary. Except for the absence of eelgrass in Clark Cove (which may be related to non-chemical stress) and the relatively high incidence of winter spleen flounder pathology, no major ecological problems were observed.... Other indications of stress...suggest subtle effects which could result from low-level exposure acting over long time periods."

Philadelphia Naval Complex

Terrestrial (potential)

"Metals are driving potential risk to receptors at PNC. Because the potential for unacceptable ecological risk cannot be eliminated for the COPCs with SQ [screening quotients] greater than one, a higher-tier, site-specific risk evaluation may be required."

Sediment (minimal)

"There is little evidence that activities at PNC are the sole source of COPCs observed in sediments adjacent to PNC...steps have been and continue to be taken at PNC to eliminate the possibility of erosion of on-site soils. For these reasons, none of the sediment COPCs should be considered to pose unacceptable risk associated with PNC."

NETC Newport (McAllister Point Landfill) (likely)

"Both organic and inorganic COC distributions indicate substantial risk to aquatic biota in the intertidal region...as compared to conditions at the reference site."

"Reduced risks at offshore stations are readily apparent...."

"Reference-based HI [hazard index] analysis of metals data show that risks are almost exclusively related to the intertidal area. Data for organics show that contamination is widespread.... These exposure-based HI data indicate significant ecological impacts in the landfill intertidal area."

"...study provides extensive weight of evidence for impacts in the intertidal zones...hence there would appear a high probability of risk occurring in this area."

NSWC Dahlgren

Site 2 (potential)

Sediment

No conclusions were given. The report simply presented toxicity quotient values (TQVs)—equivalent to HQs—indicating many exceedances.

"Despite the presence of sediment contaminants with elevated TQVs,....the structure of this community was indicative of acceptable conditions."

Soil

"The presence of these two contaminants in surface soils collected from this site represents a potential risk to ecological receptors that may use this site extensively."

Site 9 (potential)

The report summarized TQVs.

"These data indicate that aquatic and terrestrial organisms that may feed heavily on aquatic biota inhabiting this area are potentially at risk... However, macroinvertebrate data...

suggest that the benthic community in this portion of the creek can be categorized as excellent and/or acceptable despite the elevated contaminant concentrations...."

Site 10 (potential)

"Therefore, it is possible that mercury is present in concentrations that may adversely impact aquatic biota...."

"The results of analyses performed on sediment and surface water samples collected from Hideaway Pond indicate that aquatic biota are potentially at risk...." "...However, the results of the macroinvertebrate survey indicate that this community appears to be typical of... [i.e., O.K.]."

Sediments, benthicmacroinvertebrates

The ERA recommends additional study.

"However, additional sampling would be necessary to more fully characterize the extent of contamination in the pond and the impact, if any, that the presence of these contaminants may be having on the macroinvertebrate community."

Re: lead and fish

"...its ability to bioconcentrate also places top predator aquatic and piscivorous terrestrial at risk."

Site 12 (potential)

Surface water and sediment

"These data suggest that aquatic biota inhabiting this portion of Gambo creek, particularly benthic macroinvertebrates, are potentially at risk as a result of contaminants detected in this area."

However, "...the aquatic community appears to be typical of what would be expected given the salinity and other physical characteristics of the site."

Soil

"Although the macroinvertebrate community does not appear to be impacted,... the presence of contaminants which are known to bioaccumulate and biomagnify in food-chains represents a potential risk to top predators."

Site 17 (potential)

Surface water

"...these data also suggest that top aquatic and terrestrial predators that feed extensively on aquatic biota from these two tributary streams are also at risk."

Sediment

"These data suggest that benthic organisms inhabiting these two tributary streams, particularly members of the macroinvertebrate community, are at risk as a result of the presence of these contaminants."

Site 19 (minimal)

"...the actual risk posed to ecological receptors is likely to be minimal."

Site 25 (potential)

Sediment

"Animals that forage extensively in the marsh for prey items may therefore be at risk."

"Aquatic biota, particularly those associated with sediments, are potentially at risk."

Soil

"These contaminants represent a potential risk to small, ground dwelling animals....Predators feeding extensively on these types of small animals taken from the site 25 area would be at risk."

Site 29 (potential)

Surface water

No conclusions on risk were given in report, although a few exceedances were noted.

Sediment

"Aquatic biota, particularly those associated with sediments, are potentially at risk."

"Top predators feeding extensively on aquatic biota from this pond may be at risk as a result of this contamination."

MCB Quantico

No results.

Lejeune OU 1, Sites 21, 24, 78 (all potential)

Aquatic

"Overall, pesticides... have the potential for decreasing the viability of aquatic organisms at OU 1." "Therefore, other fauna that feed upon these organisms will be exposed to pesticides...."

"Pesticides...were detected in sediments at concentrations that potentially may decrease the viability of aquatic life."

Terrestrial

"Overall, pesticides... have the potential for decreasing the viability of terrestrial organisms at OU #1."

Site 21

"...lead and chromium were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species at site 21."

Site 24

"...(several metals listed) were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species at site 24."

Site 78

"...lead and chromium were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species at site 78, along with beryllium and zinc."

Lejeune OU 2, Sites 6, 9, 82 (all potential)

"Based on the above findings, past reported disposal practices at OU 2 potentially are adversely impacting the ecological integrity of Wallace Creek, Bear Head Creek, or the Ravine. The findings do not indicate a potentially adverse impact to vertebrate terrestrial receptors."

Lejeune OU 4

Site 41 (minimal)

Aquatic

"The surface waters of the unnamed tributary and Tank Creek do not show significant potential for impact to aquatic receptors from COPC concentrations except for aluminum and iron. However, these COPCs lacked an upstream to downstream concentration gradient in the tributary and the creek. The sediments of the unnamed tributary and Tank Creek do not show significant potential for impact to aquatic receptors from COPC concentrations due to the lack of upstream to downstream concentration gradients that would indicate a source area for COPCs on a site."

Terrestrial

"...any potential impacts from the seeps are limited to only aquatic receptors in the seeps itself."

Site 74 (minimal)

Sediment

"There were no COPCs detected that exceeded any sediment ARVs [aquatic reference values]."

Surface water

"...was not indicative of a significant potential for impact to surface water aquatic receptors."

Terrestrial

"There does not appear to be an impact to terrestrial organisms..."

Lejeune OU 5, Site 2 (potential)

Aquatic

"Pesticides were detected in the sediments at Overs Creek at concentrations that potentially may decrease the viability of aquatic life."

For the other two drainage areas,

"...there is not expected to be an ecologically significant aquatic population in this drainage area to be impacted."

Terrestrial

"...lead and chromium were detected in concentrations that potentially may decrease the viability of terrestrial invertebrates and floral species in the Mixing Pad Area surface soils."

"...there is a low likelihood that the COPCs in the Former Storage Area are decreasing the viability of terrestrial organisms. In the soils at the Lawn and Mixing Pad areas, there is a high likelihood that the COPCs are decreasing the viability of terrestrial organisms."

"After the proposed TCRA [time critical removal action] of soils at the Lawn and Mixing Pad areas, there is a low likelihood that the COPCs in this area would decrease the viability of terrestrial organisms."

Lejeune OU 6, Site 36 (minimal)

Aquatic

"Overall, the contaminants in the surface water and sediment have a slight potential to reduce the aquatic receptor population in the freshwater stations."

"The benthic macroinvertebrates do not appear to be impacted based on the results of sampling events."

Terrestrial

"Overall, some potential impacts [surface soil screening values] to soil invertebrates and plants may occur as a result of site related contaminants. It should be noted that there is much uncertainty in the SSSVs. There is a slight potential for decrease in the terrestrial vertebrate population from site related contaminants based on the terrestrial intake model."

Lejeune OU 6, Site 43 (likely)

Aquatic

"Based on the screening value comparison, there is a high potential for a decrease in the population of aquatic receptors from pesticides in surface water and sediments."

Terrestrial

"Overall, some potential impact to soil invertebrates and plants may occur as a result of site related contaminants. It should be noted that there is much uncertainty in the SSSVs. A potential decrease in the terrestrial vertebrate population from site related contaminants is not expected based on the terrestrial intake model."

Lejeune OU 6, Site 44 (likely)

Aquatic

The following refers to a series of bioassays:

"Therefore, the metals in surface water may be causing a decrease in survival of *C. dubia*." (Two other test species were not affected.)

"Based on the screening value comparison, there is a moderate to high potential for a decrease in the population of aquatic receptors from pesticides in the sediments. There is only a low potential for a decrease in the population of aquatic receptors from metals in the surface water and sediment and SVOCs in the sediment...."

Terrestrial

"Several SVOCs, pesticides, and metals were detected in the surface soil at concentrations that exceeded SSSVs." "Therefore, ecological receptors have a high potential for becoming exposed to contaminants in the surface soil."

"Overall, some potential impacts to soil invertebrates and plants may occur as a result of site related contaminants. It should be noted that there is much uncertainty in SSSVs. A potential decrease in the terrestrial vertebrate population from site related contaminants is not expected based on the terrestrial intake model."

Lejeune OU 6, Site 54 (minimal)

Aquatic

"...there is low potential for the remaining COPCs to cause a decrease in the aquatic life population...."

Terrestrial

The following refers to invertebrates and plants:

"Overall, some potential impact to soil invertebrates and plants may occur as a result of site related contaminants. It should be noted that there is much uncertainty in the SSSVs. A potential decrease in the terrestrial vertebrate population from site related contaminants is not expected based on the terrestrial intake model."

The following refers to animals found at the site:

"...it is unlikely that the contaminants in the surface soil at site 54 will significantly reduce the rabbit population."

Lejeune OU 6, Site 86 (potential)

"Several COPCs were detected in the surface soils at concentrations exceeding SSSVs. Therefore, there is a potential for adverse impacts to terrestrial flora, invertebrates, and/or microorganisms from these contaminants."

Referring to the habitat, the ERA stated:

"...Therefore, ecological receptors have a low potential for becoming exposed to contaminants in the surface soil due to the availability of natural habitat."

"The cottontail rabbit is the only terrestrial species with estimated CDI [chronic daily intake] values that exceed the TRV [toxicity reference value]. The QI [Quotient Index] of rabbit (2.2) just slightly exceeded 1, and therefore the COPCs at site 86 are not expected to impact terrestrial receptors (vertebrates)."

Lejeune OU 7, Site 1 (minimal)

Invertebrates and plants

"However, because the site concentrations only slightly exceed the literature values, it is not expected that these contaminants would present a significant ecological risk to terrestrial receptors."

Vertebrates

"...there does not appear to be a significant ecological risk to terrestrial vertebrate receptors."

Lejeune OU 7, Site 28 (potential)

Aquatic

Surface water

"However, these exceedances were only slightly above the reference values."

Sediment

"These exceedances represent a moderate potential for risk to aquatic receptors."

"Results of the analysis of benthic macroinvertebrate and fish populations indicate that Cogdels Creek and this portion of the New River support an aquatic community that is representative..." (i.e., undisturbed)

Terrestrial

"During the habitat evaluation, no areas of vegetation stress or gross impacts from site contaminants were noted."

"...these contaminants at site 28 may decrease the integrity of terrestrial invertebrates or plants at the site."

"...there does not appear to be an ecological risk to terrestrial vertebrate receptors."

Lejeune OU 7, Site 30 (minimal)

"Overall, there does not appear to be a significant risk to aquatic or terrestrial receptors from contaminants detected at this site."

Lejeune OU 8, Site 16 (minimal)

Aquatic

"No site related contaminants were detected in the surface water or sediment at concentrations that exceeded any of the surface water or sediment screening values. Therefore, a potential decrease in the aquatic receptor population form site related COPCs is not expected."

Terrestrial

"Therefore, there is the potential for a limited decrease in the floral and or faunal population in these areas."

"A potential decrease in the terrestrial vertebrate receptor population from site related COPCs is not expected."

Lejeune OU 11, Site 7 (minimal)

Aquatic

West Tributary

"...it appears that there is a reduction of the benthic macro-invertebrate population. However, it is not known if this reduction is from site related...."

East Tributary

"...based on exceedances of the SWSVs [surface water screening values] and SSVs [sediment screening values], potential impacts are not expected."

"Although there are some potential impacts to the aquatic receptor population, remedial actions are not warranted for several reasons."

Reasons given include: contaminants may be non-site related, the habitat is poor, and remediation may cause harm downstream.

Terrestrial

"Based on...SSVs, there is the potential for a reduction of the terrestrial floral and faunal population. However, the earthworm bioaccumulation study indicated that SSSVs appear to overestimate potential risk to earthworms."

"Overall, the potential impacts to the terrestrial population at site 7 are not significant enough to warrant remedial actions."

Lejeune OU 11, Site 80 (potential)

"Several of the contaminants at site 80 exceeded SSSVs. ...many of the exceedances were located in gravel covered areas. These areas are not likely to support an ecologically significant community."

"The contaminants in the grass covered area have the potential to decrease the population of terrestrial invertebrates and plants."

"The rabbit was the only species that had a total QI value that exceeded 1. It had a QI of 2.8, and therefore has a low potential for adversely impacting the rabbit population."

Lejeune OU 12 Site 3 (potential)

"...Many of the exceedances were located in open grass areas or along the treeline. Therefore, there is the potential for a decrease in the population of terrestrial invertebrates in these areas. It should be noted, however,...that the SSSVs are not well established and have a high degree of uncertainty."

"None of the CDI to TRV QIs exceeded 1. Therefore, potential impacts to terrestrial mammals or birds are not expected."

Lejeune OU 14, Site 69 (potential)

Aquatic

"Overall, metals and pesticides...have the potential to affect the integrity of the aquatic ecosystem at site 69."

"The fish community is healthy and not impacted due to site contaminants."

"The levels detected in the fish tissue were low when compared to published background values...."

Terrestrial

"For the terrestrial ecosystem, metals...have the potential to affect terrestrial receptors at site 69."

"Manganese was the only COPC that exceeded toxicity reference levels...for the quail." "This indicated a small potential for adverse effects to terrestrial organisms."

Allegany Ballistics Lab, Site 1 (potential)

"The general conclusion of this risk assessment is that the levels of organic and inorganic contaminants were detected at levels that exceeded standard guidelines and criteria used as an initial screening of chronic effects. These exceedances potentially represent a risk to aquatic and terrestrial resources."

Allegany Ballistics Lab, Site 2 (minimal)

"Detection of PAHs and metals with higher than background EEQs [environmental effects quotients] appears to suggest that site 2 samples present a low potential risk to wildlife."

Allegany Ballistics Lab, Site 3 (minimal)

"Trichloroethylene represents a significant risk of adverse effects for ecological resources based on the 1992 sample HCS-S3-1 detection of 49,000 µg/kg.... The 1994 surface soil sample HCS-S3-1S at the same location only had a concentration of 150 µg/kg, which resulted in an EEQ of 0.5. . .Based on the large difference in concentrations for trichloroethylene between the 1992 and 1994 samples and the relatively low quality habitat, only a very low risk to ecological resources appears to exist...."

"The overall risk of adverse effects at Site 3 is expected to be low."

Allegany Ballistics Lab, Site 4 (minimal)

"The overall ecological risk at this site is generally low."

Allegany Ballistics Lab, Site 5 (minimal)

"Although the levels of metals were not much greater than sediment quality guidelines, the presence of a viable benthic macroinvertebrate community...represents a potential risk. The size of the riverbed area with heavy metals exceeding guidelines is relatively small compared to the size of the aquatic habitat in the area and the metals concentrations are relatively low. Therefore, the environmental risk at Site 5 is considered low."

NWS Yorktown: Site 16 (minimal)

"Risk to fish and benthic macroinvertebrates are low...and these populations do not appear to be adversely impacted by these risk levels when compared to background stations."

NSGA Sabana Seca (minimal)

"Therefore, based on these calculations, no risk is expected to the surrogate wildlife species...and by extension other wildlife on the site...."

Cecil Field, OU 1

Site 1 (potential)

Surface soil

"Risks associated with surface soil were not identified for terrestrial wildlife, soil invertebrates, or plants."

Sediment and surface water

"...indicate sediment toxicity and impairment of the benthic community at 2 of 6 sampling locations.... Comparison of the adverse responses with the measurement of ECPCs (and other analyses not selected as ECPCs) in surface water or sediment did not reveal any contaminants that could be associated with the response."

Fish and terrestrial wildlife from surface water

"Risks were not identified for terrestrial wildlife resulting from exposure to ECPCs in surface water or sediment of Rowell Creek at site 1."

"The risk characterization did not identify any risks for aquatic receptors associated with ECPCs in groundwater."

Site 2 (potential)

Surface soil

"Risks associated with surface soil were not identified for terrestrial wildlife, soil invertebrates, or plants."

Sediment

"...indicate sediment toxicity and impairment of the benthic community at both of the six (sic) sampling stations."

"The adverse biological responses may, however, be associated with an orange flocculent material that blankets the bottom." (not site related)

Terrestrial wildlife from surface water

"Risks are identified for small mammals that may forage in the stream."

Cecil Field, OU 2 (potential)

Site 5

Surface soil, terrestrial wildlife

"...adverse effects to wildlife are not anticipated."

Surface soil, invertebrates and plants

At one site: "...significant worm mortality and reduced lettuce seed germination were observed."

Sediment

"...indicate impairment of the benthic community both upstream and downstream of site 5. These data suggest that the responses are associated with contamination emanating from site 5."

Site 17 (minimal)

"No risks associated with exposure to surface soil were identified for terrestrial wildlife, soil invertebrates, or plants."

"No risks associated with exposure to sediment were identified for aquatic receptors in the wetlands."

NAS Jacksonville

Sites 26, 27 (both potential)

> "Risks to small omnivorous mammals (e.g., short tailed shrew) associated with exposure to selenium and lead and risks to the meadowlark associated with surface soil concentrations of Aroclor-1260 are also possible."
>
> "In the forested stream habitat, large wading birds (e.g., herons) may be adversely affected as a result of food chain exposure to...." (lists several chemicals).

In discussing inorganics:

> "...sensitive receptors (e.g. water fleas, certain fish, amphibians) could be impacted by these contaminants although risk estimates do not suggest that the overall aquatic community would necessarily be affected."
>
> "Aquatic exposures to PCBs, which exceeded benchmark values in all three areas, may result in direct toxicological effects to aquatic receptors."

Yuma (17 sites) (all minimal)

No risk was indicated to ecological receptors.

NWS Concord

No results.

Moffett

Northern Channel (potential)

> "...adverse effects are likely in the Northern Channel from exposure to COPECs."
>
> "Adverse effects to the benthic community may have occurred in the Northern Channel. However, the environmental factors, primarily ammonia concentration, are predicted to limit the potential invertebrate population."

East and west diked marshes (potential)

"...suggests that COPECs have the potential to adversely impact invertebrates in the northeastern corner of the East Diked Marsh. However, the diversity and abundance of benthos are limited by the low DO [dissolved oxygen] and unreliable surface water."

Storm water retention ponds (potential)

"... have the potential to adversely effect the invertebrates and fish on the storm water retention ponds. However, the significance of this potential impact is mitigated by the habitat being of low quality for these receptors."

Treasure Island Naval Station

No results.

Hunters Point Annex

Parcel A (minimal)

"The ERA concludes that because of limited habitat and generally reduced contaminant levels in Parcel A, there is *de minimis* risk to terrestrial receptors in Parcel A."

NAS Whidbey Island: OU 3

Area 16 (likely)

Terrestrial

"It is concluded that potential adverse ecological impacts on vertebrate components of the terrestrial ecosystem bordering the runway ditches in Area 16 are possible from...."

Aquatic

Runway ditches, surface water. "No RME [reasonable maximum exposure] concentrations of chemicals in surface water exceeded the WQC [water quality criteria]."

Runway ditches, sediment: "It is concluded that potential risks to ecological receptors in the runway ditches in Area 16 exist for the following chemicals detected in sediment...."

Clover Valley Lagoon, surface water: "No COPCs were identified in surface water from Clover Valley Lagoon."

Clover Valley Lagoon, sediment: "...it is concluded that the potential for ecological impacts on the aquatic ecosystem in the Clover Valley Lagoon is low."

Area 31 (likely)

(Terrestrial only): "It is concluded that potential adverse ecological impacts from lead and 2,3,7,8-TCDD in soil are likely at Area 31."

NAS Whidbey Island: OU 4

Areas 39, 41, 44, 48, 49 (all minimal)

Terrestrial

"The values of the HQs suggest a low potential for substantial adverse effects."

Marine

"Toxicity screening of all surficial marine sediment locations...indicate moderate toxicity at only one location...."

FISC Pearl Harbor

Site 39 (minimal)

"The contaminants found on this site do not pose a threat to the wildlife and ecology of the site or to nearby critical habitat areas."

The ERA also notes that contaminants have not migrated off site.

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[68] Personal communication from Simeon Hahn (NAVFAC EFD North)

[69] Personal communication from Michael Pound (NAVFAC EFD Southwest)

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